CAMPBELL'S

OPERATIVE ORTHOPEDICS

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Memphis, Tenn.

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TO

WILLIS COHOON CAMPBELL

1880 1941

PREFACE TO SECOND EDITION

The primary purpose of this book is to impart pertinent orthopedic information in the light of our present knowledge, by compiling previous and contemporary operative orthopedic technics infiltrated with personal suggestions variations, and our own original technics

We have deviated as much as possible from the concise style in the first edition There, we wrote in a brief format assuming that the reader could supplement preliminary sketchy discussions with his own personal experience In this edition however we have written primarily for the fellowship man or resident keeping in mind the limits of his experience and have assiduously set forth preliminary data where we deemed it necessary to apply properly certain surgical technics To accomplish this aim less than one-half of the manuscript is preserved in its original form from the first edition One-third of the illustrations have been eliminated and replaced by twice their number Three new chapters Preoperative and Postoperative Care Peripheral Nerve Injuries and Amputations have been added New sections have been written on Mold Arthroplasty Ruptured Intervertebral Discs and Difficult and Unusual Non unions.

Some of our readers may feel that rare or less common lesions occupy too much space and the common operations are treated too lightly We believe however, that we may rightly presume that the fellows and residents will be well versed in the more common procedures, and will value this book not only for its inclusion of the most recent variations and improvements of these technics, but even more so as a reference book for these unusual lesions For it is not so much the deftness in handling the simpler procedures that distinguishes the more competent surgeon, but the ability to diagnose accurately and treat the exceptional cases In keeping with this merit the index has been carefully prepared to guide the reader to these sections with a minimum of effort Our addition of an Author s Index should also prove to be of benefit.

If the reader is aware of a current operative technic that he fails to find included in this text he must not hasten to assume that the efficacy of that technic is necessarily unsatisfactory or that we have been negligent Often several technics for the same procedure are available with only slight *variations* and with essentially similar results Our choice here lay, respectively with those technics with which we were the most familiar the most recent variation of an old principle those availed with the most detail or in some instances, those accompanied with the best illustrative material

If we have attributed credit imprudently we shall gladly amend this blunder We can only add with sincerity that we have tried to recognize and honor our many sources of information Faced with controversial or contrasting schools of thought we have permitted our amalgamated experiences, and careful consideration to guide us in our selections for this book. Though we have merely acknowledged but not expounded upon opposing views, this was not done with a dogmatic stand rather it was in consideration for the size of this text

We apologize to our foreign colleagues for the limited and rather incomplete references to their scientific achievements. This is not an intentional slight of the many fine studies and original procedures that undoubtedly have been carried out the contingencies of war interrupted the flow of literature and information was unobtainable. In our next edition we will make these inclusions

J S Speed
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PREFACE TO FIRST EDITION

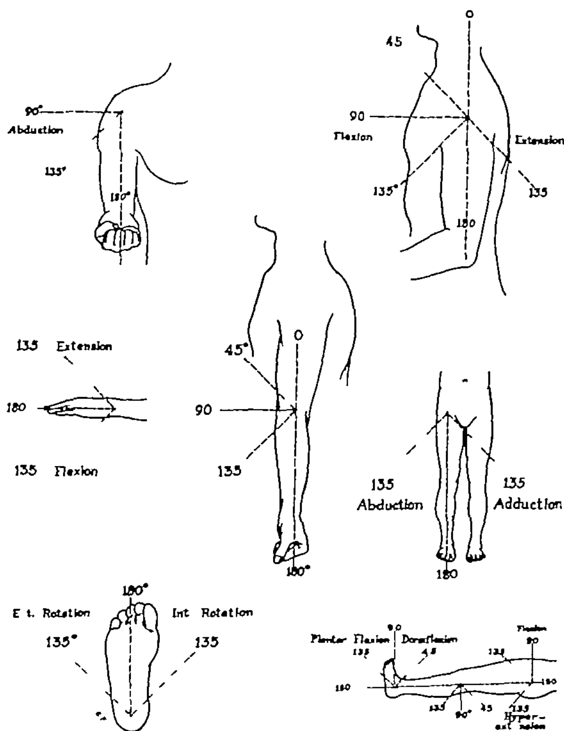
The title of this book, "Operative Orthopedics," is not intended to convey the impression that the chief or most important method of treatment of orthopedic affections is open surgery. Although many orthopedic affections are best treated by operative measures alone, the majority are successfully treated by more conservative means. Further, such measures are often essential adjuncts either before or after operation.

This volume has been written to meet the current need for a comprehensive work on operative orthopedics, not only for the specialist, but also for many industrial and general surgeons who are doing excellent work in some branches of orthopedic surgery, and are making valuable contributions to this field.

The evolution of orthopedic surgery has been exceedingly slow as compared to that of surgery in general. Not until aseptic technic had been materially refined was surgery of the bones and joints feasible. The statement is often made that the World War afforded the experience which made possible the rapid development of orthopedic surgery during the past two decades. The surgery of the war, however, was chiefly the surgery of sepsis, there was little of the refined asepsis which is required in reconstruction surgery. Undoubtedly, the demonstration during the war of the necessity and importance of this field led many able men to specialize in orthopedics, and to them considerable credit is due for its subsequent progress.

No classification of orthopedic affections is entirely satisfactory, consequently any arrangement of operative procedures is subject to similar criticism. With the exception of the chapters on Arthroplasty and Arthrodesis *operations described in this text are grouped together according to their applicability* to a given affection. This involves less repetition as to generalities of etiology, pathology and treatment than would be necessary in a classification according to anatomic location. Operative procedures appropriate to two or more affections are described in the discussion of the one wherein they are most commonly employed.

To overcome the too widespread conception of orthopedic surgery as a purely mechanical equation an effort is made in the first chapter of this book to correlate the mechanical, surgical and physiologic principles of orthopedic practice and throughout the book to emphasize the practical application of these physiologic principles. A special chapter has been written on surgical technic, for the purpose of stressing certain details in preparation and after treatment which vary to some extent from those described in works on general surgery. A thorough knowledge of these phases of treatment is a requisite to success. To avoid constant repetition, chapters have been included on apparatus and on surgical approaches, repeated reference is made to these chapters. The after treatment is given in detail for practically all operative technics. This is a most essential yet too often neglected factor in the success of any surgical treatment.


90°
Abduction
135°
180°
0
45
90
Flexion
Extension
135°
135
180
135 Extension
180
135 Flexion
0
45°
90
135
180°
135
Abduction
135
Adduction
180
180°
Ext. Rotation
Int Rotation
135°
135
Plantar Flexion
Dorsiflexion
Flexion
90
180
Hyper-
extension

In giving the position or range of motion of a joint, only one system has been followed With the exception of the ankle and wrist, the joint is in neutral position when parallel with the long axis of the body in the antero-posterior and lateral planes. As the joint proceeds from the neutral position in any direction, the number of degrees in which such movement is recorded decreases progressively from 180 to 170 160, and so on, to the anatomic limit of motion in that particular direction To illustrate, complete extension of the knee is 180 degrees, when the joint is flexed 30 degrees, the position is recorded as the angle formed between the component parts of the joint, i e., the leg and thigh, or 150 degrees. Flexion to a right angle is 90 degrees, and full flexion 30 degrees In the wrist the joint is at 180 degrees, or in the neutral position when midway between supination and pronation and flexion and extension In the ankle joint, motion is recorded as follows the extreme of dorsiflexion 75 degrees, right angle 90 degrees, and the extreme of plantar flexion, 140 degrees.

In some instances the exact end results have been given to the best of our knowledge So many factors are involved in any one condition that a survey of end results can be of only questionable value unless the minute details of each case are considered Following arthroplasty of the knee for example, one must consider the etiology pathology, position of the ankylosed joint, the structure of the bones comprising the joint the distribution of the ankylosis, and the age of the patient, in estimating the end result in each case Further a true survey should include the results of *all* patients treated over a period of *many* years, and should be made by the surgeon himself, rather than by a group of assistants, or by correspondence.

In our private clinic and the hospitals with which we are associated, a sufficient amount of material on every phase of orthopedic surgery has been accumulated during the past twenty years or more to justify an evaluation of the various procedures From this personal experience we also feel that definite conclusions may be drawn in regard to the indications, contraindications, complications and other considerations entering into orthopedic treatment. In all surgical cases, mature judgment is required for the selection of the most appropriate procedure With this in mind, the technics which have proved most efficient in the author's experience have been given preference in the text. In addition after a comprehensive search of the literature operative measures have been selected which in the judgment of the author are most practicable.

Although no attempt has been made to produce an atlas of orthopedic surgery an effort has been made to describe those procedures which conform to mechanical and physiologic principles and will meet all individual requirements In any work of this nature there are sins of omission, also many surgeons in the same field may arrive independently at the same conclusions and devise identical procedures We have endeavored, however, to give credit where credit was due If there are errors, correction will gladly be made In some of the chapters we have drawn heavily from authoritative articles on special subjects the author gratefully acknowledges his indebtedness for this material. He also wishes to thank those authors who have so graciously granted permission for the reproduction of original drawings

In conclusion I cannot too deeply express my sincere appreciation and gratitude to my associate Dr Hugh Smith who has untiringly and most efficiently devoted practically all of his time during the past two years to collaboration with me in the compilation and preparation of material, which alone has made this work possible I also desire to express appreciation to Dr J S Speed for his collaboration on the sections on Spastic Cerebral Paralysis and Peripheral Nerve Injuries to Dr Harold Boyd for anatomic dissections verifying all surgical approaches described, and for his assistance in preparing the chapter on this subject to Dr Don Slocum for his aid in the preparation of the chapter on Physiology and Pathology, to Mrs Allene Jefferson for her efficient editorial services, and to Mr Ivan Summers and Mr Charles Ingram for their excellent illustrations.

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J S S
H. S

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VOLUME I

CHAPTER I

PREOPERATIVE AND POSTOPERATIVE CARE

Much of the following discussion may seem elementary and superfluous We wish however, to point out the necessity for the most meticulous observance of every detail of the preoperative preparation, the technic of the surgery, and the postoperative treatment. Since each is vital, not only to the actual execution of the operation, but also to the prevention of subsequent complications, the neglect or careless performance of a single detail may undo all that the most skillful surgeon is able to accomplish.

PREOPERATIVE PREPARATION

The requirements of proper treatment begin with the examination and preoperative care of the patient. Regardless of the nature of the operation to be performed, the patient's general condition should first be thoroughly studied. If this is satisfactory elaborate preparations are unnecessary the routine measures are sufficient. The preoperative care of patients in poor physical condition must be governed by the demands of the individual case The subsequent discussion will deal particularly with the latter

General Medical Preparation

The records of orthopedic patients usually include accurate and complete details of the local condition, yet neglect the past and present history and the findings on examination of the other systems. In considering any patient for surgery, attention is too often centered upon the local condition, with entire disregard of general conditions which may have a tremendous bearing upon the outcome. All factors, both local and general, which may influence the patient's convalescence and ultimate recovery should be carefully evaluated Fortunately, the 'latitude of chance has been broadened to some extent during the past few years by improvements in surgical technic, methods and means of internal fixation of fractures, and by progress in the science of anesthesiology

A common sense appraisal of the patient's attitude and desire to get well is a requisite to successful surgery Elaborate psychologic studies are unnecessary Emotional instability, personality deviations, or subconscious or conscious mental reservations regarding surgery however may adversely affect the end result The majority of orthopedic operations demand the cooperation and the expenditure of considerable effort on the part of the patient during the convalescent period The benefits of the most skillfully performed reconstruction procedure can be nullified by an uncooperative patient.

An adequate diet is of paramount importance In the appraisal of the surgical risk in elderly individuals, this is especially true Many of these pa

tients suffer from clinical and subclinical avitaminosis incident to poor eating habits or to some more or less minor illness which is accompanied by anorexia. Poor mastication, also often contributes to the state of malnutrition. This vicious cycle frequently results in a state of hypoproteinemia. Obviously all such physiochemical defects should be corrected if feasible before the patient is subjected to surgery

A history of allergic reactions, including hay fever asthma, urticaria, and serum sensitivity may prove invaluable in the selection of certain types of treatment, *such as prophylactic serum therapy* *Fortunately*, most of the manufacturers of biological antisera have treated the sera so as to alter the species (despeciated) and thus have materially reduced the danger of anaphylaxis. Similarly one should determine whether the patient has any drug idiosyncrasies. Many patients will thus be saved considerable annoyance from drug rash or from attacks of nausea and vomiting Common offenders are the opiates, cinchona derivatives, and one or more of the barbiturates.

Every candidate for surgery should be closely questioned for evidence of a previous cardiovascular renal disease. If such evidence is found, the indicated system or systems should be investigated by appropriate clinical and laboratory tests, and the ability of the affected part to withstand the burden to be imposed upon it by the contemplated surgical procedure, should be weighed. If, in the history or on physical examination evidence of myocardial disease is found an electrocardiographic tracing should be made Also if the history leads one to suspect kidney damage, blood chemistry studies, such as blood urea and non protein nitrogen determinations are indicated If glycosuria is found, further blood studies should be carried out to establish the presence or absence of diabetes mellitus.

If the occasion demands, special studies, such as roentgenograms of the lungs, or thorough appraisals of the competency of the blood supply to an extremity should be made

A hemoglobin estimation total white cell and differential blood counts, Wassermann Kline, or Kahn tests, and a urinalysis should be made routinely prior to either major or minor operations. The patient s blood should be typed and, if a female in the child bearing age, the Rh factor should be determined. Blood of an individual with an opposite Rh factor should not be given for example if a female recipient s blood is Rh negative only blood from an Rh negative donor is suitable. In every major operation on the thigh hip spine, or shoulder blood which has been cross-matched with that of the patient should be available for use at a moment s notice We give blood transfusions to all elderly individuals during major operations. The coagulation time and bleeding time should also be investigated routinely before surgery is undertaken, to determine the presence of hemophilia or any disease of a purpuric nature, and if necessary a platelet count should be made

Preoperative Preparation of Elderly Patients—In rendering an opinion as to the approximate surgical risk in individuals who have passed sixty years of age, it is well among other things, to give a high score to the patient who is mentally alert, with bright facial expression and bright eyes, whose skin has a good turgor who is well hydrated, and who has a relatively normal blood pres-

sure The patient with hypotension, malnutrition, anemia, fast pulse, loose skin with low turgor, dehydration, and sluggish mental faculties, is a poor surgical risk These patients should receive restorative and supportive measures before any major surgical procedure is undertaken One or more pints of blood should be given, together with amino acids enterally or parenterally if blood proteins are low, and 5 per cent glucose intravenously every eight to twelve hours until water balance is restored In the arteriosclerotic, mentally sluggish patient, nicotinamide, given orally, 100 mg three or four times every twenty four hours, with cortical extract (Cortate), 5 mg hypodermically every twelve hours for five doses and then daily for five doses appears to be of definite value



Fig 1.—As a surgical risk, give a high score to the elderly patient whose skin has a good turgor who is well hydrated and mentally alert, and who has a relatively normal blood pressure. Patient, aged 91 years, up in wheel chair on first postoperative day after nailing of fracture of hip. Her physiologic age is less than her chronologic age.

To prevent meteorism Prostigmine should be given orally 15 mg every four hours the day before surgery, and hypodermically (ampule form 1 4 000 or 1 2 000 dilution) for two or three days following surgery If ileus develops despite these measures, 0.5 c.c. of Pitressin followed in 20 minutes by a flatus enema, will bring relief unless intestinal obstruction is present. Lyo B-C is an effective vitamin preparation both before and after operation, particularly in the elderly individuals. The dried material dissolved in 5 c.c. of water may be added to a quart of glucose and given intravenously or may be dissolved in 2 c.c of water and given intramuscularly once daily The patient seems to have less meteorism while receiving this preparation.

In the presence of impending myocardial failure, the patient should be digitalized prior to operation. Digitoxin (Digitaline Nativelle) 0.8 mg. to 1.2 mg. as an initial dose will digitalize the patient within eight to twelve hours. Thereafter 0.1 mg. tablet daily or every other day will suffice to maintain digitalization.

The preoperative preparation of the average diabetic patient is no longer difficult. If diabetes is first discovered at the time of the patient's admission for surgery, one should take time to study the diabetic condition as to its severity, controllability and intractability, unless emergency surgery is required. If one is in doubt as to which is more important, the diabetes should be studied first and brought under control, the dosage of insulin being standardized and stabilized, before operation. Too much emphasis cannot be placed upon the importance of keeping the diabetic patient well hydrated at all times. If this cannot be done orally, fluids may be given intravenously. If saline or glucose is given parenterally, regular insulin should be given hypodermically in the ratio roughly of one unit of insulin to two grams of dextrose, in order to facilitate metabolization of the excess glucose.

Local Preparation

For the average operation, the skin is thoroughly cleansed twelve hours previously with green soap and water, shaved well above and below the contemplated operative field, and sponged with fat-solvent solutions, such as benzine or gasoline. These solutions are then thoroughly removed with ether to prevent a chemical dermatitis. The operative field is next painted with half-strength tincture of iodine, which in turn is removed with 70 per cent alcohol. In applying antiseptics to the skin of blonde individuals, one must be exceedingly careful to remove all excess solutions, particularly tincture of iodine; otherwise, a chemical dermatitis will result and necessitate postponement of the operative procedure. One should also avoid applying tincture of iodine to skin which has previously been covered with an ordinary mercurial preparation. Similar precautions must be observed in the operating room. Sterile towels are applied with careful aseptic technic and firmly affixed with rolled bandages and adhesive tape, to preclude exposure of the prepared area.

For operations about the hands or feet, the skin, including all recesses, must be scrupulously cleansed, and the nails trimmed. Children from rural districts who have been going barefoot should be prepared in this manner for a period of at least two or three days before any operation about the feet is undertaken. As an additional precaution, the feet should be soaked in 0.25 per cent chlorozene solution for twenty minutes three times daily. To these patients without exception, an immunizing dose of tetanus antitoxin should be administered the day before operation. We have had three deaths from failure to observe this precaution; one of the patients had been prepared for two days, and the other had received preoperative preparations over a period of one week. The use of tetanus toxoid alone is not appropriate; the time required to build up an active immunity by toxoids unnecessarily delays the operative procedure.

Patients who have worn casts and splints for a long period of time, and whose skin is therefore dirty and exfoliated, should be prepared for a period of

three to seven days A green soap poultice is applied to the skin for twenty four to forty-eight hours, and followed by daily gentle cleansing with water until every vestige of loose skin has been removed After thorough cleansing the skin is exposed to the air and to dry heat at frequent intervals until its texture and appearance are relatively normal No solutions are applied until one or two days before operation, as half strength antiseptics are used, there should be no irritation

The various regions are prepared for operation as follows If the operation is to be on the foot and ankle, the extremity should be prepared to the knee and if on the knee the area of preparation should extend from the ankle to the groin. When a graft is to be removed from the tibia, the entire leg should be prepared from above the knee to well below the ankle

For operations about the hip preparation should extend from the midline of the abdomen at the level of the umbilicus well around the back, including the buttock on the affected side, and down to the knee. All hair should be shaved from the pubis and the region of the gluteal cleft, as well as from the abdomen, thigh, and back.

The area of preparation for operations on the sacroiliac and lumbosacral regions should cover the back from the proximal end of the gluteal cleft to the level of the middorsal vertebrae. For other areas of the spine the back should be prepared at least five vertebrae above and five below the operative field and laterally well over the chest.

Operations on the shoulder call for preparation from the base of the neck and upper third of the sternum to the elbow, and posteriorly over the scapula, special attention being given to the cleansing of the axilla. Preparations for operations on any area distal to the shoulder should include the arm, forearm wrist, and hand.

In general hospitals preparatory measures are often poorly executed, the chief errors being inadequate shaving irritation of the skin by shaving or scrubbing and failure to prepare a sufficient area If an additional area must be prepared on the operating table, the preliminary preparation is a waste of time.

POSTOPERATIVE CARE

Efficient after treatment calls for a corps of well trained and intelligent nurses who are familiar with the possible complications attendant upon various orthopedic operations. Much anxiety and apprehension on the part of the surgeon, and many embarrassing and unnecessary complications may be avoided by frequent observations. At no time are the services of an intelligent nurse of more value to a patient than during the immediate postoperative period. She should know and be on the alert for signs of shock or other complications, and should institute nursing measures and notify the surgeon forthwith, the surgeon should include in his postoperative orders sufficient information to give the nurse a comprehensive idea of the proper treatment The orders should concern first, the patient s general condition and second, the local condition

General Postoperative Care

Water balance should be maintained by means of 5 per cent glucose, with or without physiologic saline, every eight to twelve hours, depending on the

patient's requirements. If the patient is losing chlorides by emesis or Levine tube, the glucose should be given in physiologic saline otherwise infusions of glucose in saline and water alternately will suffice. In maintaining water balance by parenteral fluids one should check the blood chloride to prevent edema incident to a preponderance of sodium ions. When necessary vitamins, such as Lyo B-C may be added to the glucose solution If thiamine chloride is given intravenously caution must be exercised to avoid severe and possibly fatal reaction.

Suction should be employed when necessary as a precaution against the aspiration of foreign material into the lungs. A mixture of 95 per cent oxygen and 5 per cent carbon dioxide should be given in amounts sufficient to combat cyanosis, to prevent atelectasis and to facilitate deeper inspiration until the patient reacts from the anesthesia. If the patient is slow in regaining consciousness as is sometimes observed following the administration of sodium pentothal two or three ampules (3 mg each) of picrotoxin in a quart of glucose may be given intravenously Much larger amounts have been given in divided doses to the deeply narcotized patient, with beneficial effect. Coramine and metrazol are also good analeptic agents As a safeguard against hypostatic pneumonia, explicit orders should be given to have the patient s position changed every two hours during the day and every three or four hours during the night. This is particularly important in elderly individuals.

In many cases, operations are performed on bones which were formerly the site of an infectious process. Although the disease may not have been active for years, the possibility of relighting a dormant infection and thereby inducing serious complications both locally and generally, is ever present. For these patients antibiotic therapy is routinely administered before and after operation. Antibiotics are also frequently employed to prevent postoperative infection following extensive traumatic surgical procedures.

Local Postoperative Care

Orders relative to the patient s local condition should include adequate information as to the exact position in which the patient and the member should be maintained. While the operation is in progress, preparations should be made in the room for the reception of the patient. Bradford frames, fracture beds, or various types of suspension apparatus should be in readiness for use if needed.

When casts are applied a heat cradle or cast drier should be placed across the cast routinely to insure rapid drying After twelve to twenty four hours the patient should be turned on the abdomen with care to avoid *breaking the cast, and the posterior surface of the cast dried in a similar* manner In operations upon the distal portion of the extremities the elevated position helps to prevent excessive postoperative swelling and reaction

Symptoms of Impairment of Circulation From Apparatus

After the application of any apparatus, whether splint brace, or cast, for an acute condition or following operation the patient must be carefully watched for signs of constriction of circulation. When splints have been applied to the upper or lower extremity the fingers or toes should be under constant surveil

lance until all danger of pressure induced by swelling from an acute reaction has passed. This requires from three to four days, and in some cases a week. There are a few cardinal signs which should be known to every physician nurse or attendant (1) Pain extreme or excruciating, (2) cyanosis or blanching (3) swelling, (4) depressed local temperature, (5) diminished sensation, (6) loss of motion and (7) sudden unexplainable elevation of temperature

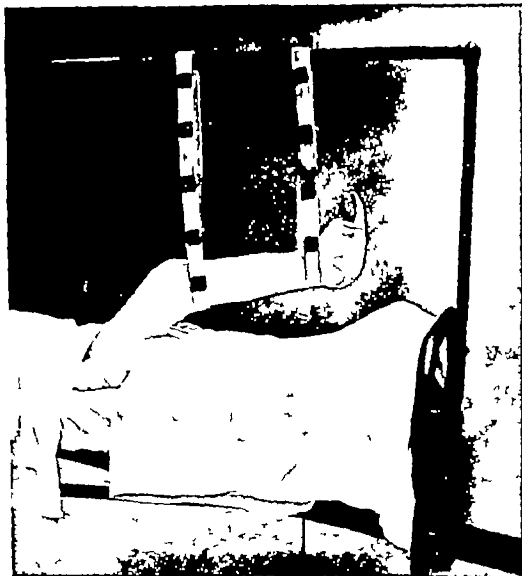


Fig. 2.—Method of suspending long leg cast in elevated position. Provides patient with some freedom of movement.

The majority of patients complain of pain, some more than others, but intense continuous pain in one locality should be investigated that the possibility of a serious complication from pressure may be excluded. Cyanosis is an indication of venous stasis, usually from superficial pressure. Anemia, or sudden blanching indicates impairment of the arterial circulation possibly thrombosis, and may therefore be of grave consequence. Swelling and depressed local temperature are significant only when associated with other signs. Diminished sensation, if slight, is not serious, but complete loss of feeling usually points to damage to the nerves, especially if associated with loss of motion in a previously functioning member

Diligent and constant care should be given by a competent attendan the physician should be notified at once if any of the above signs are obs In the presence of constriction, a portion of the splint or cast should be rei at once to permit inspection. *If no improvement takes place, the entii paratus must be removed and the position of the limb changed.* Undoub by careful observation and postoperative treatment, many limbs may be from permanent and unnecessary impairment and many disastrous com tions may be averted.

Arterial Obstruction.—Occasionally, obstruction of the arterial blooc ply to an extremity occurs as a direct result of trauma. Whether the ar phenomenon is the result of a laceration of an artery with thrombosis, or severe vasospasm even the exact location of the pathology may be purely s lative without the aid of arterial radiograms. In any case, steps should be *immediately to release the reflex spasm* by one of the following methods a paralumbar sympathetic ganglion block by means of a local anesthesia (caine 1 per cent) (b) continuous caudal anesthesia (metycaine 1.5 per c (c) continuous regional spinal anesthesia, (d) surgical excision of the tl bosed artery We relegate the surgery of arterial obstruction to those wh versed in this field.

The efficacy of one of the above methods of therapy was illustrated i case of a boy aged sixteen, who was admitted to the clinic six days after a ball injury which resulted in an epiphyseal separation of the proximal epiphysis. The injury was followed by loss of function, loss of pulse swe pain and anesthesia almost to the knee The skin was cold over the lower fifths of the leg Continuous caudal anesthesia with metycaine 1 5 per cen instituted and continued for seven days and nights. Thereafter amput below the knee was possible.

If the arterial spasm incident to the trauma is not relieved within eig twelve hours from the time of the accident, one may be certain that a subst portion of the extremity distal to the site of trauma will be lost. On the trary if vascular spasm can be released within the first six to ten hours prospect of preserving the extremity is favorable

Wound Healing

Primary healing of a wound is dependent upon two factors. The first i virulence and number of organisms in the wound despite observance strictly aseptic technic the absolute sterility of the wound is always ques able. The second factor in primary healing is the resistance or def mechanism of the individual both locally and generally The rean powers in bone are slowly mobilized and are not comparable to thos the abdomen and soft tissues. For this reason, every effort should be r to follow an aseptic technic which will interfere with the local def mechanism to the least possible degree. Briefly the following points sh be observed

1. **Trauma.**—The technic should be as atraumatic as possible. Exce blunt dissection and rough handling or crushing of the tissues adds an unn sary burden of repair increases the postoperative reaction both systemic

and locally, and leads to fibrous tissue formation in the operative field which may add to the difficulty of subsequent procedures

2. **Hemostasis**.—Hemostasis should be secured with a minimum amount of suture material In many cases, needless ligatures and the necrosis incident thereto may be obviated by gentle pressure or packing When employed, ligatures should be so placed as to strangulate the soft tissues as little as possible

3 **Foreign Material**.—During many operations upon bone wherein drilling is necessary small particles of bone are scattered through the soft tissues of the wound Loose fragments of bone, either in the joints or soft tissues, act as foreign bodies and a source of irritation and are not conducive to healing To prevent dissemination and facilitate complete removal of loose particles of bone, the area may be packed off with small sterile sponges Regardless of how inert foreign material such as wires, or rustless steel or Vitallium nails may be, these must always be regarded as foreign bodies and their use should be limited. From this standpoint autogenous or absorbable material is preferable in every case when feasible.

4 **Operating Time**.—The rapidity with which an operation is carried out should be commensurate with careful exposure and dissection hemostasis and efficient performance Undue prolongation of operating time because of inefficiency of the operating room personnel unnecessary attention to minor details, or long discourses for teaching purposes, is to be condemned The possibility of air-contamination of the wound should not be underestimated, the longer the wound remains open the greater the danger of infection. When an operation is necessarily of long duration the tissue should be moistened at frequent intervals with normal saline When two or more incisions are required undue exposure to the air may frequently be prevented by temporary closure of a wound with towel clips.

5 **Closure of the Wound**.—Accurate approximation of the edges of the wound by properly placed sutures is of prime importance in healing When large sections of soft tissue have been resected an effort should be made to close completely all dead spaces. ' Although suture material should be used as sparingly as possible the number and strength of the sutures should be consistent with tension, in order to prevent rupture of the wound

6 **Immobilization**.—In surgery of the extremities, regardless of the type of procedure, the joints should always be immobilized when the wound is likely to be disturbed by motion. Further healing will take place within a shorter period of time if when feasible, the joints are immobilized in a position which will release tension on the suture line.

7 **Dressings**.—In many operations on the extremities performed in a bloodless field wounds are closed prior to the release of the tourniquet. In these cases, a pressure bandage should be applied this should be sufficiently snug to secure hemostasis, yet not so tight as to obstruct circulation As a rule the dressings are not removed until healing is adequate to prevent the possibility of contamination Often the dressings applied in the operating room are left in situ until the skin sutures are removed on the twelfth or fourteenth day Silk sutures beneath a cast are frequently undisturbed for one or two months, or even longer Only in the presence of excessive pain swelling or a systemic reaction is the wound examined.

Although high fever is regarded by some physicians as a useful method of combatting infection, the consensus is that more harm than good may result from excessively high temperature (104-105 degrees) Fever should therefore be combatted with acetylsalicylic acid (Aspirin), tap water, ice bags and alcohol sponges.

If high temperatures are prevented hyperhidrosis is reduced in the majority though not all patients. Dehydration should be prevented by the oral and parenteral use of fluids.

It has been estimated that a patient who has a continuous high temperature may lose as much as 250 Gm. of protein daily This loss should be restored by the intravenous administration of amino acids, or by dehydrated proteins (Delcos) by mouth.

The following measures if effectively enforced, provide our best insurance against amyloid degeneration destruction of the etiologic agent as quickly as possible administration of fluids to dilute and neutralize toxins the institution of restorative measures to combat the secondary anemia and loss of weight and, finally, the maintenance of a proper diet including ample proteins.

Ileus—Vomiting

Formerly, ileus was a common, troublesome and distressing postoperative complication, particularly after long, shocking operations, such as arthroplasty of the hip It develops in some degree in practically all patients with a fractured vertebra or severe trauma to the dorsolumbar region of the spine, or with any condition wherein the supine position must be more or less enforced.

In the prevention of ileus, the patient should be given prostigmine 15 mg., four doses daily beginning the day before surgery this is continued by hypodermic (ampules of 1-4 000 dilution) for two or more days postoperatively If this has no effect, 0.5 c.c. of pitressin, followed in twenty minutes by a flatus enema, will usually relieve the condition Before resorting to the latter measure, one must be reasonably sure that no intestinal obstruction is present Diathermy to the back and hot fomentations to the abdomen may be of value in relieving the condition. In obstinate cases, continuous regional spinal anesthesia may be given by means of a Touhy needle and a small catheter A Levine tube passed through the nose into the stomach, with an attached Wangensteen suction apparatus, is especially valuable in treatment of dilatation of the stomach.

If vomiting persists, the stomach should be washed out through the Levine tube with a warm 2 per cent solution of sodium bicarbonate until the contents are clear Thereafter 2 c.c. of dilute hydrochloric acid in a glass of water are introduced into the stomach, and the tube is clamped for one hour This procedure is repeated every two hours until vomiting is controlled. Uncooked foods, fruit juices, or milk, if given within the first forty-eight hours after major surgery are likely to produce distention and initiate vomiting

Anemia

In a strict sense, we no longer think of anemia as either primary or secondary In this discussion, we are not interested in the so-called primary anemias, wherein the mean corpuscular volume is greater than 90 cubic microns, and the mean corpuscular hemoglobin concentration is greater than 30 per cent.

We are interested in anemias due to the following causes (a) loss of blood from surgical procedures (normocytic), (b) acute destruction of blood, as in malaria, (c) anemia incident to destruction of blood cells and depression of hemopoietic centers by septic processes, and (e) anemia from deficiency of iron in the diet, or from failure of assimilation of the iron (microcytic)

The treatment of anemia incident to blood loss, whether acute or chronic, consists of removal of the cause of the depletion of the blood and replacement by whole blood Thorough hemostasis is of paramount importance in every surgical procedure If loss of blood during a surgical procedure is unavoidable, the patient should receive blood in adequate amounts during or immediately following operation

In orthopedic patients, the next most common causes of anemia are acute or chronic inflammatory processes, malignancies, and a lack of iron The treatment of the microcytic forms of anemia should be directed toward the elimination of the primary process, when possible, and the institution of an ample diet, the use of blood transfusions, and the administration of adequate amounts of iron by mouth. Patients with microcytic anemia which does not respond to iron therapy should be studied for achlorhydria. If necessary dilute hydrochloric acid may be given.

Too often, the amount of iron prescribed is insufficient. Iron and amonium citrate 1 5 to 3 Gm., or ferrous sulphate 5 grain tablets, three to eight per day after meals, are usually ample There are scores of proprietary preparations which combine liver and iron these may be utilized if the simpler measures are inadequate. In many arthritic patients whose anemia is ascribed to the use of gold therapy the above measures may be augmented by the intramuscular use of concentrated liver extract (1 c c —15 units) with definite beneficial effect

Complications Incident to Prolonged Recumbency

Phlebothrombosis and Thrombophlebitis—The best treatment for these lesions is prophylaxis. Since the exact etiology is frequently obscure, it naturally follows that any preventive measures suggested may be open to question. Assuming that lack of exercise is a factor bicycle exercises (Fig 4) or so-called four-count exercise is utilized when feasible, i e., the hip is flexed to 145 degrees with the knee extended with the hip fixed at 145 degrees, the knee is next flexed touching the opposite knee with the heel, then returned to the straight position, and the extremity is lowered to the bed. This is repeated from five to twenty times every two hours through the day If active exercises are impossible or inadvisable, an attendant may institute the exercises passively, following the same technic.

For the past fifteen years, it has been our practice to institute general passive exercise' to the affected limb in the fashion described above, as soon as the diagnosis of thrombophlebitis is made, or even suspected. These exercises are performed every two hours, and are increased in number from five to twenty for two to three days at the end of this time pain, tenderness and swelling usually begin to subside. Thereafter the patient continues active exercise of the extremity Many patients have been treated by this method with favorable results. The rapidity with which the affected limb returns to normal and the systemic fever subsides is often rather astonishing

Fig. 3.—Four-count exercise. A useful routine in prophylaxis and treatment of thrombophlebitis.

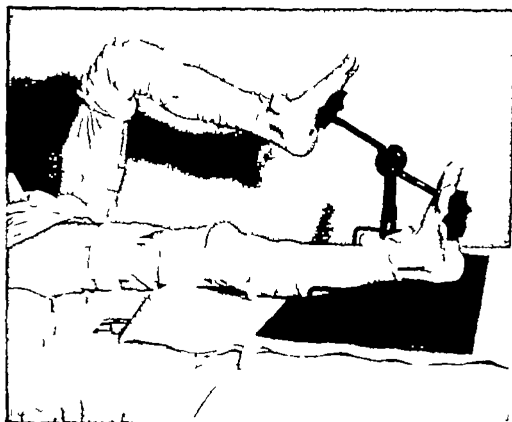


Fig. 4.—Bicycle exercises for recumbent patient maintain vascular and muscular tone of extremities. A practical means of prophylaxis against thrombophlebitis, and of preventing muscular atrophy of lower extremities.

Parasympathetic lumbar block with Novocain or other anesthetic agents may be applied with profit, especially in exceptionally obstinate cases which respond slowly to exercise. Despite its present popularity, we have not observed a need in our practice for vein ligation. In cases of phlebothrombosis, however, ligation of the vein proximal to the thrombus may be in order.

Genitourinary Complications (Cystitis, Pyelitis, Nephrolithiasis).—Here, again, the best treatment is prevention. A sustained water balance is of primary importance. A frequent change of position is necessary. A change of the reaction of the urine from acid to alkaline, and again to acid, every three to seven days by the alternate administration of ammonium chloride and potassium citrate, is helpful. Highly seasoned foods and allergens, which may irritate the genitourinary tract should be withheld. If the patient is to be confined for several weeks, a mild antiseptic, such as urotropin with ammonium chloride or sulfadiazine with sodium bicarbonate should be given a few days and omitted a few days.

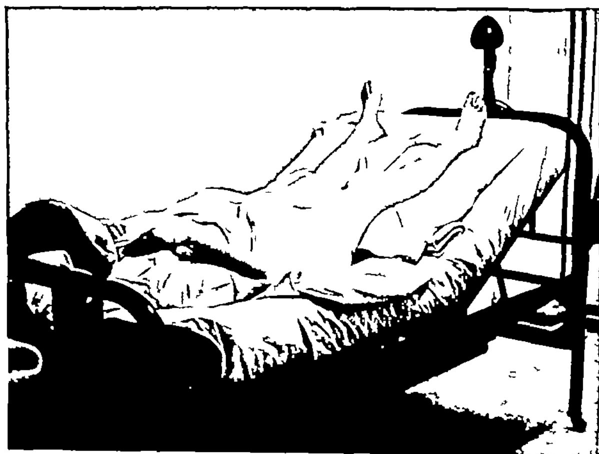


Fig. 5.—Simple and comfortable method of maintaining both lower extremities in elevated position by reversing patient in bed.

One should be on the alert to prevent retention of urine since this complication may lead to serious damage of the urinary tract. If the patient cannot empty the bladder thoroughly, a "bag catheter" should usually be introduced into the bladder. The catheter should be attached to an irrigator apparatus and the bladder thoroughly lavaged every four to six hours with a mild antiseptic solution such as boric acid or acriflavine 1:5 000 dilution. The same treatment is indicated in elderly individuals who have cystitis, associated with relaxed sphincters and leaky bladders.

Hypostasis.—Changes of position every two or three hours and deep breathing exercises are of paramount importance in preventing and treating hypostasis of the lung Penicillin, if used early may prevent a pneumonitis this may be administered intramuscularly or by inhalation through a nebulizer in combination with oxygen

Decubitus.—Decubitus is ordinarily preventable in a well managed patient. After its development, the treatment should consist of cleanliness, keeping the skin and ulcer dry the application of dry heat, air baths, and prevention of trauma. If the ulcer is grossly infected topical applications of antiseptics such as potassium permanganate 1 1 500 dilution or some other agent, such as 0.5 per cent cysteine hydrochloride or antibiotics, as penicillin or tyrothricin, may be applied with benefit.

ANTIBIOTIC THERAPY—SULFONAMIDE THERAPY

The patient who has been subjected to a prolonged surgical procedure should receive penicillin 30 000 to 50 000 units, every three hours intramuscularly for four to five days. This is especially true if the field of operation is a large one, as in arthroplasty of the hip Fever and a leucocytosis is the rule, rather than the exception following operations of even less magnitude upon the extremities and cannot, therefore, be construed as evidence of bacterial infection. A temperature of 103° F., and a leucocyte count of 15 000 may be seen following a simple fracture For the lack of a better explanation we consider such systemic reactions due to protein absorption and perhaps autolysates, as result of devitalized tissues.

In the presence of an active local staphylococcus or streptococcus infection, penicillin is the antibiotic of choice. This drug is effective in some measure against almost all infections produced by the gram positive bacteria, whether cocci or bacilli. It is also effective against a few of the gram negative strains, such as the gonococcus and meningococcus. A total of 200 000 to 400 000 units *should be given daily being divided into equal doses and administered intra*muscularly every three hours. Its use should be continued until the infection is eradicated or until the patient has been free of fever for one week.

If, after four or five days of penicillin therapy no clinical improvement is apparent, one should consider that the offending bacterium is probably resistant to penicillin a change in the form of penicillin is then in order If there is still no improvement, one of the sulfonamides should be given instead of or together with further penicillin.

In severe infections such as acute osteomyelitis or acute infectous arthritis penicillin therapy should be given in heroic doses Therapy should be instituted even on the suspicion of the presence of a bone or joint infection. In the majority of these patients, the etiologic agent is the ubiquitous hemolytic staphylococcus thus, fortunately resistance to penicillin is the exception rather than the rule.

If treatment in acute hematogenous osteomyelitis is begun sufficiently early usually one may reasonably predict that chronic osteomyelitis may be prevented Surgical drainage may be unnecessary With the aid of penicillin and without surgical interference, we have seen small sequestra disappear only osteosclerosis

remaining at the site of infection. In the presence of acute osteomyelitis with sepsis and with a positive blood culture, penicillin should be given in the vein almost continuously by adding 500,000 units to 1,000 c.c. saline and allowing it to drop at the rate of 35 to 40 drops per minute. As many as 5,000,000 units, intramuscularly and intravenously, have been administered in 24 hours without harmful effects. In severe infections, as gas gangrene, massive doses are necessary.

One of the chief disadvantages of the use of penicillin therapy is its rapid elimination from the body by the kidneys; it is estimated that 80 per cent is excreted through the tubules and 20 per cent by glomerular filtration. For this reason the patient must be disturbed every three hours by hypodermic injections. Recent experimental work leads one to hope that, in the future, it may be possible to raise the minimal plasma penicillin concentration (0.03 units per c.c.) two to seven times by giving concurrently a new drug Caronamide. Further clinical experiments with this drug are now being carried out.

In addition to penicillin two other antibiotics, i.e., tyrothrycin and streptomycin have been popularized within recent years. They have not received the acclaim of penicillin chiefly because of the expense of production, scarcity of supply and, with regard to streptomycin especially, the unfavorable toxic effects. These antibiotics are most useful in infections caused by gram negative bacilli, whereas penicillin is the drug of choice for infections caused by gram positive cocci and bacilli.

Streptomycin therapy in bone infection produced by the mycobacterium tuberculosis is being enthusiastically received in many quarters. Reports of workers on this subject are sufficiently promising to encourage further and more intensive effort in the therapeutic management of bone tuberculosis as well as tuberculous meningitis. The dosage and duration of treatment has not been definitely determined; the daily dosage recommended by different experimenters varies from one Gm. (1,000,000 units) to 2.5 Gm. (2,500,000 units).

Penicillin Reaction.—We have not observed any serious side effects from the use of penicillin. However many patients with allergic tendencies develop untoward reactions, the most common being fever or dermatitis. If the patient is receiving penicillin prophylactically and the wound looks good and the leucocyte count is low, stop the penicillin. The febrile reaction if due to penicillin will gradually subside.

A dermatitis from the administration of penicillin is usually a maculo-erythematous rash on the trunk, extremities, or both, and is frequently accompanied by pruritus. Calamine lotion provides temporary relief. The rash disappears in a few days after discontinuance of penicillin.

Reference

Crosson, J. W., Boger, W. P., et al.: Caronamide for Increasing Penicillin Plasma Concentrations in Man, J. A. M. A. 134: 1528, 1947.

CHAPTER II

APPARATUS

In the majority of orthopedic affections, the intelligent application of w constructed and properly fitted apparatus is just as essential to treatment] operatively or postoperatively as the skillful execution of the surgical tech In many affections, the use of apparatus alone may suffice. When not prop selected and utilized, however, apparatus may not only fail to accomplish desired purpose, but may produce further disability

To obviate the necessity for repetition in subsequent chapters, the n and methods of construction and of application of apparatus routinely emplo will be described.

Apparatus serves the following purposes

1 To prevent deformity As a rule, apparatus for this purpose must used continuously for a long period of time and therefore must be so construc as to permit walking when possible

2. To maintain position enforce rest, allay muscle spasm relieve pain to separate inflamed or irritated joint surfaces.

3 To correct deformity This is accomplished by apparatus so construc as to apply gradual force in such directions as may be necessary to restore a p to the normal anatomic or most useful position.

4. To restore function by gradual cultivation of motion in the joints.

The apparatus commonly employed in the treatment of orthopedic affecti consist of plaster or plastic casts, splints, braces, traction devices, and vari special apparatus for inducing motion, all of which are adapted to meet the quirements of the individual case. When the extremities are involved, *joints generally are maintained by apparatus in that position which will aff* the most useful member in the event of ankylosis or restricted motion. Tl is called the most serviceable or the optimum position

CASTS

Routine Plaster of Paris Casts

An efficient cast calls for the use of uniform plaster bandages of go quality If either plaster or crinoline of poor quality is used, or the bandag are improperly rolled, a soft and grainy cast, or one which is so brittle as crack on the least strain, may be produced.

Plaster of Paris is anhydrous calcium sulphate. The setting time m vary from three to thirty minutes, *depending upon the nature of its manufa* ture proper plaster should set in from five to seven minutes. 'Activators such as potassium sulphate, borax zinc sulphate sugar or sodium chloride m be added to reduce the setting time unless they are mixed in the correct propo tions, however the plaster becomes brittle and the cast breaks upon the lea provocation. The setting time is best regulated by varying the temperature the water cold water retards, and warm or hot water facilitates the proce

The period of time the plaster is allowed to soak also has some influence upon the setting time as well as upon the strength of the plaster

The best foundation material for plaster bandages is No 12 mesh crinoline The crinoline should be sized or stiffened with starch, rather than with glue, since glue may not only retard, but actually prevent consolidation of the plaster To test the crinoline for starch, a strip of the material is inserted in a weak solution of iodine in water If starch is present, the reaction to the iodine will cause the crinoline to turn blue. Crinoline may now be purchased in continuous rolls of the desired widths (usually two three and six inches) with serrated borders to prevent fraying at the edges.

Plaster bandages are best made by rubbing plaster into the meshes of the crinoline by hand, filling all the interstices of the fabric. If an excessive amount of plaster is used, or if the bandage is rolled too tightly water will not uniformly permeate the bandage If the bandage contains too little plaster or is rolled so loosely that the plaster shakes out into the water the cast will not consolidate well, will break easily and dry slowly

Plaster reinforcements, to increase the strength of casts at necessary points, are made of the same widths as the plaster bandages, i e., two three, and six inches, and of varying lengths from two to four feet. Reinforcements are prepared in a manner similar to that followed in making plaster bandages, being folded layer upon layer until of six or eight thicknesses. The completed fold is rolled up and held by a rubber band Both bandages and reinforcements are preserved in large cans in a dry place.

Commercially made plaster bandages are usually more expensive and less well adapted to general use than those made by hand. Their quality however is uniform which is not always true of the handmade type. The hard coated commercial plaster bandages are ideal for the occasional user

Technic of Application.—Stockinet and a thin layer of padding of outing flannel or sheet wadding are applied, conforming closely to the contour of the part the bony prominences should be especially protected to prevent pressure The padding must not bind and must be free from wrinkles and knots, as irregularities of any kind may cause pressure. In applying outing flannel as a padding one should remember that it is not elastic and thus may be a factor in impairment of circulation especially in post traumatic and postoperative cases. If sheet wadding is used, a muslin or gauze bandage is applied snugly over the wadding to insure conformation. One or two gauze or muslin strips are inserted longitudinally beneath the padding and allowed to extend beyond each extremity of the cast. These strips may be caught at each end and pulled to and fro to induce friction and scratch the itching skin

An amount of water sufficient to saturate all bandages thoroughly should be in readiness in large receptacles otherwise the plaster may be precipitated in the water preventing further wetting of the bandages If one must wait for water to be brought, the cast may dry in layers and become weak or brittle by the inclusion of air spaces. The bandages must be applied without interruption.

Two or three plaster bandages of the desired dimension are immersed in a pan or bucket of water the temperature having been regulated to conform to the desired setting time After all bubbles disappear usually from two to three

minutes, the bandage is grasped in both hands, one hand over each end, to prevent the escape of plaster and lifted from the water By slightly twisting the hands in opposite directions and at the same time bringing them together to form a bulge in the middle of the bandage the excess water is expelled.

The use of Freiberg paper aids in preventing expulsion of the plaster from the bandage The bandage is wrapped in a porous paper napkin and bandage and paper are immersed in the water Since the paper is porous, the water passes through and saturates the bandage yet little plaster escapes. The wet paper is then peeled off the bandage which will be found to contain a uniform amount of plaster

The bandage is applied by circular turns, conforming closely to the bodily contour Constriction at any one point must be avoided otherwise the bandage will wrinkle and cause pressure upon the skin and perhaps decubital ulcers. Bandages are applied in layers until the cast is of durable thickness. Much time may be saved and the efficiency of the cast increased by the use of longitudinal plaster reinforcements steel, wire, or wood reinforcements and other materials do not adhere adequately to the plaster As needed, the reinforcements are immersed in water and placed over the points of greatest strain, being retained in position by additional circular bandages. As each layer is applied, the bandage is rubbed strenuously to insure uniform cohesion and thus afford the maximum strength In the roentgenogram a properly applied cast will appear as a solid mass, whereas in an improperly applied cast many air spaces will be demonstrated. To provide firmer fixation the cast should be molded to the bony prominences as setting occurs, although undue pressure of the cast must be avoided. All molding and rubbing should be done before that time in the setting process when immobility of the plaster is a requisite for the proper setting If the plaster is disturbed thereafter the crystals fail to interlock properly and the ultimate strength of the cast is impaired *Until the plaster has firmly set* the cast must be suspended, or supported on pillows otherwise, the weight may cause indentations and consequent pressure of the skin The cast is trimmed as desired and the stockinet or padding is cut at the top and bottom turned back over the cast, and fixed in place by means of a plaster bandage. This procedure not only improves the appearance of the cast but prevents particles of plaster from falling into the cast to the discomfort of the patient *If excessive swelling is likely large windows should be cut or the cast should be bivalved and the segments held together by gauze bandages to permit immediate release of constriction should there be evidence of pressure or interference with the circulation*

Skintight Plaster of Paris Casts

We occasionally employ a skintight plaster of Paris cast as advocated by Böhler particularly for immobilizing fractures of both bones of the leg When a skintight cast is indicated however one must usually anticipate considerable reaction in the soft tissues, with consequent swelling In such cases, the cast must be cut to prevent ischemia and its advantages are therefore partially lost.

Technic (Böhler) —The skin is thoroughly cleansed with green soap and water and alcohol, and a reinforcement or plaster splint is applied longitudinally to the posterior surface of the extremity For the thigh, the re

inforcement should be five inches in width and should extend from well above the buttock to the ankle, for the leg the reinforcement should reach from just below the knee to the heads of the metatarsal bones. For the forearm, the reinforcement should be three inches in width and should extend from the upper third of the arm to the dorsum of the hand just proximal to the metacarpal bones. The extremity should not be shaved, by allowing the plaster to solidify and include the hairs, a material advantage in immobilization is secured The smooth side of the reinforcement should be placed next the skin One should also take care to prevent wrinkles, else decubital ulcers are inevitable.

The reinforcement should conform to the extremity, especially about the bony prominences. At the ankle knee and elbow this is facilitated by cutting darts in the reinforcement on both sides of the joint A thin layer of outing flannel or muslin padding is then wound smoothly around the reinforcement and the plaster is allowed to set with the bones and joints in their proper position A routine circular cast is then applied Should impairment of circulation appear likely casts on the lower extremity are split down the anterior surface and spread Böhler warns that this should be practically routine for fractures of both bones of the leg For fractures of both bones of the forearm the cast is cut on its radial aspect and spread

Plaster Splints

The plaster splint is made by applying wet plaster reinforcements to the part and fastening these with gauze bandage. If prepared reinforcements are not available, successive lengths of bandage of the desired dimensions are overlapped, each layer being rubbed into the preceding layer The strength of the splint will depend upon the number of layers of bandage used Upon completion the splint is applied as described above. The gauze bandage which holds it in place should not cause constriction. Before setting, the splint may be trimmed with scissors or after setting with a cast knife.

The underlying skin should not be shaved before the splint is applied, since the hairs afford a measure of fixation If the skin is excoriated or otherwise damaged, stockinet or a thin layer of sheet wadding may be first placed over the area this however, is not desirable and should be avoided, if possible

Plaster Pattern Technic

In this technic, the part to be immobilized must first be measured, usually by making a paper pattern If an extremity is to be immobilized, the measurement is best taken of the uninjured limb The measurements are marked on the muslin or crinoline and the pack is cut, the number of layers used being determined by the size of the patient and the desired strength of the cast To allow for shrinkage the patterned crinoline should be approximately 10 per cent larger than the size of the area to be covered

Plaster of Paris is sprinkled over the surface of the water the temperature of which may be varied according to the requirements of setting until it is no longer absorbed. The mixture is then stirred until an even cream is produced The pattern is next immersed into the cream and loosely rolled up When thoroughly saturated, the pattern is removed from the solution gently squeezed

to remove excess fluid, and immediately spread over the injured part and carefully molded to the surface The pattern may be placed directly upon the skin or upon padding Several turns of plaster bandage are applied to hold it in place. Large casts may require reinforcements to insure complete rigidity

This technic calls for more specialized knowledge of plaster application than the plaster bandage technic but when mastered will be found most useful.

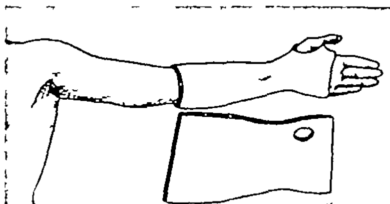


Fig. 6.—Plaster pattern cast for immobilization of wrist. (From Trueta, J The Principles and Practice of War Surgery St. Louis, 1943 The C. V Mosby Co.)

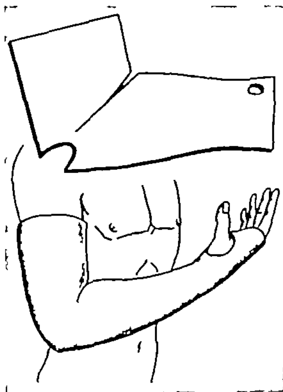


Fig 7

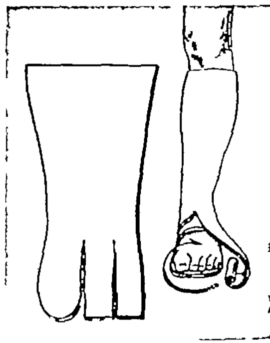


Fig 8.

Fig. 7—Plaster-pattern long-arm cast. (From Trueta, J The Principles and Practice of War Surgery)

Fig. 8.—Plaster-pattern technic for immobilization of foot and ankle. The foot is placed between the straight segments, the curved lateral strap being used to cover heel and plantar region. (From Trueta, J: The Principles and Practice of War Surgery)

Walking Casts

Walking casts are designed to permit weight bearing with a maximum amount of fixation. This type of cast is particularly useful in delayed union, when weight-bearing may be the deciding factor between nonunion and solid

union. Further early weight bearing in a cast is a means of preventing an undesirable degree of atrophy and osteoporosis in many affections of the lower extremity

Technic.—A routine plaster cast is applied this may be a boot cast, long leg cast, or single spica cast, depending upon the site of the lesion The weight bearing surface on the sole of the cast may be prepared in a number of ways (1) reinforcements may be folded back and forth to form a flat surface (2) balsa wood a very light substance may be cut in the shape of a foot and incorporated on the bottom of the cast with a few turns of plaster (3) a simple rubber heel may be tacked to a canvas strap and the ends of the canvas included under the last few turns of the plaster, thus fixing the rubber heel to the bottom of the cast according to the method of Stryker, or (4) a walking iron or stirrup may be applied, as advocated by Böhler The stirrup consists of a U shaped metal piece with a small platform at the base for a weight bearing surface approximately two inches distal to the heel, the lateral bars extend well up on the leg and are incorporated in the plaster

Plastic Casts and Splints

Plastic materials, of which cellulose is the chief component, have been introduced as substitutes for plaster of Paris to provide immobilization. Castex and Aire-lite are examples of these materials. None however, have met with universal approval Although they possess several advantages over plaster, being waterproof light in weight and permeable to roentgen rays, they also have certain disadvantages, i.e., difficulty of application, slow setting time, inflammability and shrinkage.

Although not well adapted to acute traumatic work, plastic casts may be useful in cases of injury to the upper extremity wherein prolonged immobilization is required, as in fractures of the carpal scaphoid.

SPLINTS

A splint is a temporary apparatus for fixation and support, while a brace may be regarded as an ambulatory splint, designed for permanent or long continued use Splints are often worn only at night, after the ambulatory brace is removed. Night splints are applied more easily if fitted with pads, and buckles and straps of webbing or leather An apparatus which is to be subjected to unusual strain should be constructed of tempered steel Aluminum is often preferred for splints used in the treatment of fractures, being more permeable to roentgen rays than other metals and thus permitting roentgenologic examination without removal of the apparatus.

Convalescent Plaster Splints

When a greater degree of mobilization is desired than is afforded by the routine metal splints, and apparatus must be removed daily from the extremities or trunk for exercises, physical therapy or heliotherapy bivalved plaster splints or casts will be found both efficient and economical The treatment is carried out while the patient lies in either half of the cast.

Technic.—A routine circular cast of the desired thickness is applied, with only stockinet between the plaster and skin. As a rule, additional support is supplied by an increased number of longitudinal reinforcements. Steel rods may be bent to the proper angles and incorporated in the plaster on the

anterior and posterior surfaces, if desired. When sufficiently dry which usually requires from twenty four to forty-eight hours, the cast is bivalved. Each half is then thoroughly dried in a baker the stockinet is discarded, and the cast is relined with a thin layer of felt which overlaps the edges. To hold the two halves together straps with buckles are affixed by brads to opposing points.

Bennett has devised an excellent plaster splint which is light and inexpensive and is preserved by a celluloid coating

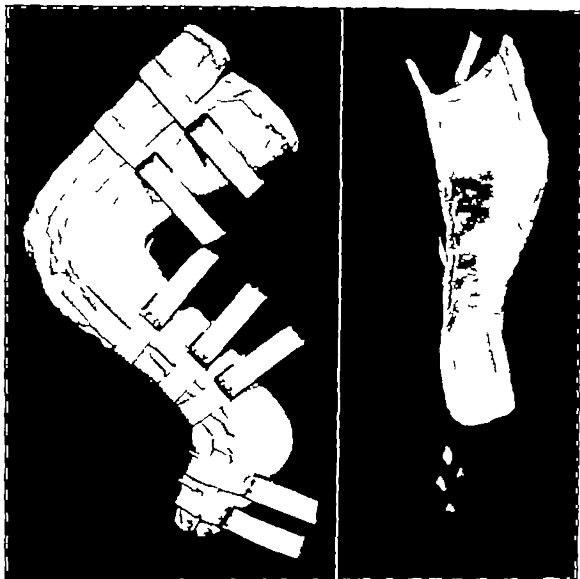


Fig. 8—Convalescent plaster of Paris splints.

Technic (Bennett)—The skin is protected from the wet plaster by a thin layer of stockinet or talcum powder The required number of reinforcements are thoroughly moistened applied one upon the other to form a half cast, and rubbed well together If desired, narrow strips of sheet metal shaped to the proper contour may be incorporated in the plaster The reinforcements are molded to the part and held in proper position until the plaster sets. This obviates the necessity of plaster bandages or of applying a circular cast.

While the plaster is still moist, the half cast is removed without disturbing the mold, and allowed to dry, baking in an oven will materially expedite drying The rough edges of the splint are covered with plaster and the inner surface is smoothed with fine sandpaper

After the cast is thoroughly dry, a waterproof covering is added, made and applied by the following formula To a two-quart jar two thirds filled with cellulose acetate flakes (viscosity 5), three ounces of dimethyl phthalate "A" is added, and the jar is filled with acetone sealed, and set aside for three or four hours, the contents being stirred occasionally When first made, the mixture is clear and of a consistency slightly thicker than ordinary paint. Since the acetone tends to evaporate a further amount must be added to maintain a syrupy consistency This mixture is highly inflammable and should be kept away from open flames until dry thereafter the danger is slight

Titanium dioxide a chemically inert compound may be added to this formula for the purpose of making the solution white and opaque Three to four drams to two quarts of the mixture is sufficient

The cellulose acetone mixture is applied to the cast or splint with an ordinary paint brush Usually, three coats are necessary intervals of five to ten minutes being allowed for drying between each application. The cast must be dried thoroughly and the mixture applied on days of low atmospheric humidity as the mixture absorbs moisture and will not adhere to the plaster This is of the utmost importance

BRACES

Braces to be used in the treatment of orthopedic affections must conform to the contour of the region to be supported. They must be ordered from the bracemaker with as much care as is exercised in writing a prescription to the druggist.

Technic.—For the routine type of brace, a tracing of the region is made on ordinary strong wrapping paper the pencil being held close to the skin and perpendicular to the paper that the contour may be accurately reproduced On this tracing should be noted the location and type of the joints, as well as the circumferences about which circular bands and straps are to be applied By following this pattern, the mechanic can make the apparatus conform to the outline of the part.

When exact conformation is required a plaster of Paris model of the part must be made. The plaster is closely applied over shirting all padding being omitted, and after drying is cut longitudinally and removed. The edges are held together with a roller bandage while the bracemaker fills the shell with plaster of Paris to make a form over which the appliance is to be constructed

Steel, being extremely durable, is most satisfactory for the construction of braces. When lightness of weight is desired metals such as Duraluminum may be employed This material is especially adaptable to the fabrication of splints, spinal braces, and braces used in the treatment of spastic cerebral palsy It is less satisfactory for making joints, the latter are best made of steel the lighter metal being reserved for the other parts of the brace.

FRACTURE TABLES

A most important part of the orthopedic surgeon's armamentarium is a properly constructed fracture table. In the majority of orthopedic clinics this table serves a double purpose, being employed also as an operating table thus, transfer of the patient from a routine operating table to the fracture

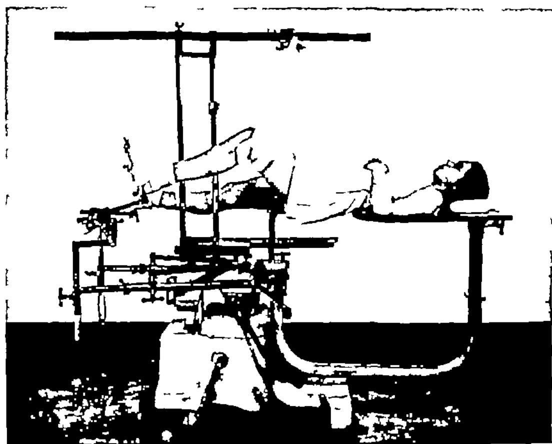


Fig. 10—Comper Albee fracture table. (Courtesy of American Sterilizer Co., Erie, Pa.)

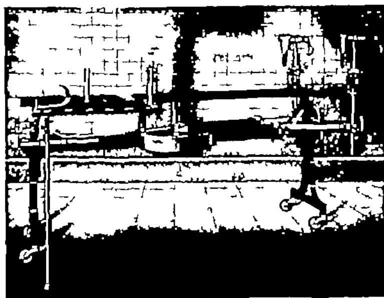


Fig. 11—Hawley-Scanlan fracture table. (Courtesy of Scanlan Morris Co.)

table for the application of a cast following operation is unnecessary In our experience, the most efficient fracture tables are the simplest The Hawley Scanlan, Comper Albee, and Bell tables are well constructed and, although each presents certain individual advantages and disadvantages, all are satisfactory The Bergamini table is a departure from the ordinary types, presenting many features which make it adaptable to a variety of uses

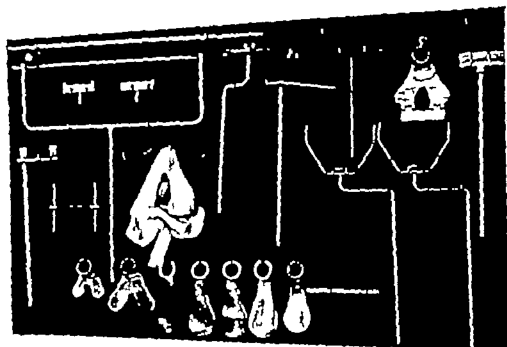


Fig 12.—Board for display of parts to a fracture table, that they may be readily available and may not be displaced or lost.

THE FOOT

Casts and Splints

In all affections of the toes, fixed hyperextension should be prevented This may be accomplished by a plaster of Paris cast which is molded to the contour of the flexed toes. The cast should reach to the upper third of the leg and if desired, may be applied in two segments first, from the upper third of the leg to the base of the toes, holding the ankle joint in 90 degrees flexion when this has consolidated, the section over the toes is added while the toes are held in flexion To permit free inspection of the toes, the dorsal surface of the cast should be trimmed back to the base of the nails. A special type of cast is utilized to maintain correction after bunion operations (Fig 1061)

Flexion of the toes may also be maintained by a splint of aluminum or malleable metal, made from a tracing of the sole of the foot The splint

is bent to correspond to full plantar flexion of the metatarsophalangeal joints, and is thinly padded by a covering of adhesive plaster or gauze. A strip of adhesive about the foot and heel binds the splint close to the sole of the foot while the toes are held in plantar flexion by a strip of adhesive one-half inch in width. A gauze bandage is then wound snugly around the entire foot and splint. Frequent inspection is necessary as a precaution against slipping of the adhesive and consequent extension or dorsiflexion of the toes.

When weight bearing is instituted after affections of the forefoot and toes, an elevation of the sole of the shoe just posterior to the metatarsophalangeal joints is often required. The width of the elevation should correspond to the number of toes involved. A night splint, consisting of a sole plate with an elastic band attached to hold the toes in plantar flexion, may be necessary A splint or suitable arch support may be worn in the shoe during the day

Arch Supports

Arch supports are valuable adjuncts to the treatment of many affections of the foot particularly in the presence of valgus or planus deformity or when slight supination or mild varus of the foot is desirable. The supports must conform to the contour of the foot, therefore, should be made over a plaster of Paris model of the foot, as follows A plaster cream is prepared and poured into a shallow pan. The foot is immersed in the soft plaster to above the arch, without pressure on the plantar surface. The plaster is molded about the inner border of the foot and heel and allowed to consolidate. The mold is then removed, smeared with petrolatum and filled with fresh plaster cream By this means, an accurate model of the sole of the foot is obtained

If a model of the entire foot and ankle is desired this may be made by applying circular plaster bandages directly to the skin. After the plaster partially sets, the model is split over the dorsum of the foot and ankle, carefully withdrawn from the foot and the cut edges are exactly approximated and held by bandages. This mold is then filled with plaster cream reproducing an accurate model of the foot

Whitman s method is even more accurate. The model is made with the patient seated in a chair Before him is placed a stool of somewhat less height than the chair with its top inclined at an angle of 45 degrees. A large mass of plaster cream is poured upon a cloth, then, with the patient s knee flexed the leg externally rotated, and the foot in slight equinus, the outer side of the foot is gently pressed into the plaster until more than half is covered. As the plaster rests upon an inclined plane the force of gravity tends to hold the foot in slight adduction. When the plaster has set, its upper surface is coated with petrolatum or talcum powder and the remainder of the foot is covered with plaster The two halves are then removed and bound together and the mold is filled with plaster cream to produce the model.

Arch supports may be made of steel Monel metal, or alloys of various kinds. The illustrated arch which is made of leather reinforced with cork, with a triangular metal plate beneath the arch proper has proved satisfactory

Other types of less rigid supports, such as those made of felt or sponge rubber may also be employed to advantage Dickson and Diveley use one made of sponge rubber of fairly firm consistency and having two parts, to care for

both the longitudinal and metatarsal arch These supports are made in three sizes and are ground to fit after the foot has been measured The technic of sizing and shaping requires care and accuracy but is not difficult.

Metal supports constructed of steel, Monel metal, or aluminum are often necessary in severe deformity These should be fashioned over a plaster model of the foot and should extend from the heel to the heads of the metatarsal bones, curving upward along the inner border of the arch to the level of the tubercle of the scaphoid bone. The support may be nickel plated, which makes a smooth finish or galvanized, which makes a more durable covering If necessary a leather covering or an inner sole may be placed on its upper surface



Fig. 13—Leather cork arch support in progressive stages of construction. Metatarsal pad attached to completed support.

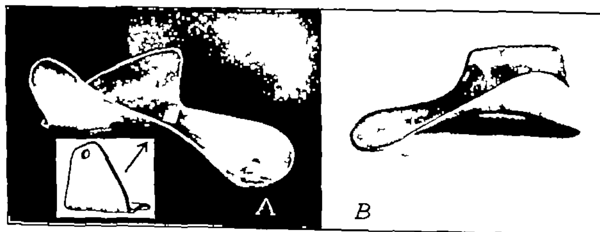


Fig. 14.—A Roberts heel. Metal wedge shown in insert is bradded to support beneath arch. B Whitman metal support.

Whitman Support.—This brace is made from an outline drawn upon a plaster model, as previously described, and is molded to fit the bottom of the model. The best sheet metal 18 to 20 gauge should be used. The sole part pro-

vides a firm, comfortable support, yet reaches only from the center of the heel to just behind the head of the first metatarsal bone and therefore does not restrain the normal movements of the foot. A broad, internal upright portion rises well above the scaphoid bone, covering and protecting the astragaloscaphoid joint. An external arm covers the calcaneocuboid junction and the outer aspect of the foot to a height sufficient to hold the foot securely. The weak part of the foot is thus clasped and held by two upright flanges.

Roberts Support.—Metal plates which embrace the heel as devised by Roberts, are designed to maintain the upright position of the os calcis, being based upon the theory that pes planus is caused by outward rotation of the os calcis. These are often used for young children. The support is molded over a plaster impression of the foot and made to extend from the heel to the ball of the foot. The inner border of the foot is raised by tilting the floor of the plate under the os calcis with a *small metal lug*. *A thumb like flange* engages and presses upon the inner side of the heel near its posterior extremity.

Metatarsal Pads

For temporary support, metatarsal pads are made of heavy saddler's felt. These are one eighth to five-sixteenths inch thick and are semiovoid in shape. They should be placed immediately behind the head of the affected metatarsal bone and held in situ by adhesive tape.

Metatarsal supports of a more permanent type are constructed of fine mesh semiresilient rubber. The latter are attached to leather arch supports or sewed in proper position on the inner soles of the shoes.

Shoes

The feet must often be properly balanced by shoes modified to meet the requirements of the case. The question of proper shoes is more difficult to solve in adults than in children and in women than in men. Generally speaking, laced shoes are preferable for young children, and high shoes are more effective than low quarters. The shoe should be of ample length and width to avoid crowding the toes, the inner border should be straight and the counter should grip the heel firmly to promote stability. Heels should not be placed on children's shoes until they reach the age of five or six years, since heels limit the normal range of motion at the ankle joint. In adults, heels facilitate walking by inclining the body slightly forward; when too high, however, they throw excessive strain on the forefeet and crowd them forward into the narrowed part of the shoes. French heels also afford a very small base for support and cause insecurity of the foot.

Valuable adjuncts to the correction of varus and valgus deformities are especially constructed shoes which hold the foot in partial supination or pronation, yet present a fairly pleasing appearance. The desired effect may be produced by raising the heel with leather taps on the inner or outer sides of the heels or toes, in an endeavor to produce toeing in and supination of the foot, or toeing out and pronation. Neutral or straight last shoes which may be used on either foot are available.

During World War II rigid steel bars were employed successfully in march fractures of the metatarsals in soldiers. A steel bar ½ to ⅝ inch wide, ⅛ inch

thick and 6 inches long, was countersunk on the under side or nonweight bearing surface of the sole and fixed in place by four rivets This bar held the shoe sufficiently rigid to permit continued training It may be used to advantage in any condition requiring a rigid sole.

Toe Board

The toe board (Fig 15) provides an excellent means of exercising the flexors of the toes to prevent hyperextension Further, strengthening of the intrinsic muscles by this apparatus helps to maintain a transverse arch The board is twelve inches long and eight inches wide and the top is inclined from the center in order to force the foot into slight varus and adduction A notch anteriorly permits "gripping movements" of the great toe on both flexion and adduction The toes protrude over the front edge of the board to permit flexion

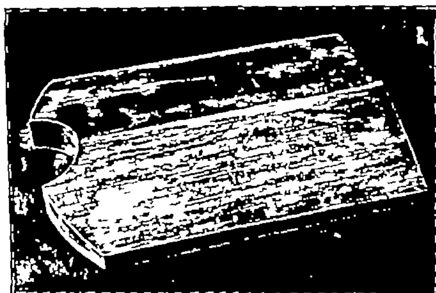


Fig. 15.—Board for exercising toes. Slanting surfaces enforce inversion of the foot.

THE ANKLE

Because of the close relation of the ankle and foot, both are often involved in the same pathologic process or are traumatized at the same time In such an event, the ankle and foot are treated together, according to similar principles. In affections of the ankle, the foot should be maintained at a right angle to the leg if motion becomes limited further movement from this position usually is developed by walking Should ankylosis ensue 90 degrees is the most useful position Care should also be taken to prevent ankylosis in dorsal flexion as walking on the heel produces an awkward gait.

Casts

The foot may be maintained at a right angle to the leg by a plaster of Paris cast, when feasible, or by a special splint. The cast, which is more comfortable and effective should extend from the tips of the toes to the tibial tubercle anteriorly and posteriorly two inches below the joint or to a point which will allow easy flexion of the knee.

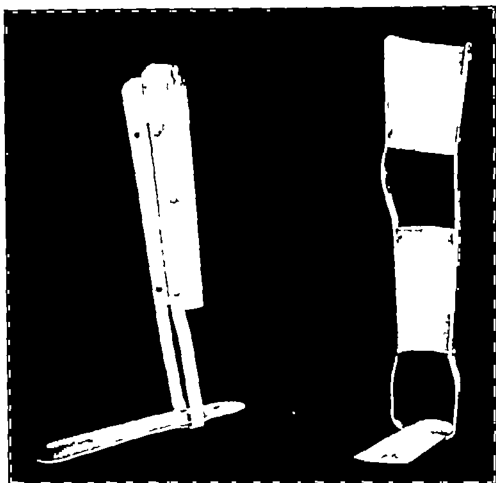


Fig. 16.—Short and long convalescent or night splints.

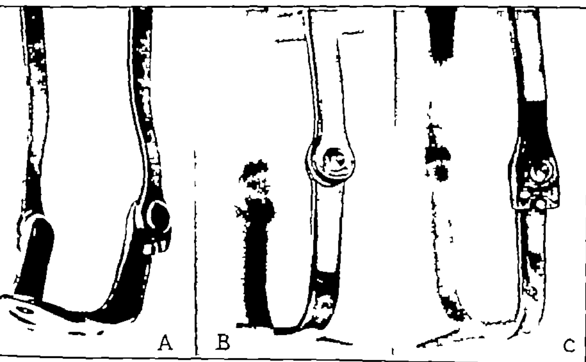


Fig. 17.—Joints for ankle braces. *A* Joint to permit dorsiflexion but prevent plantar flexion beyond 90 degrees, same joint in reverse is used to prevent dorsiflexion past 90 degrees. *B* Free motion joint. A brad renders the joint rigid if desired. *C* Limited motion joint.

the same proportions as the ankle splint. The two lateral steel bars are connected above by a metal band posteriorly below the bars are connected to a stirrup which is fastened to the sole of the shoe or to a sole plate inserted into the shoe. Joints, so constructed as to permit movement and function in the proper directions and to the proper degrees, are incorporated in the brace at the level of the ankle joint No lateral movements are permitted in any type of ankle brace, as only the anteroposterior function, or plantar and dorsal flexion is required. The joints may be constructed according to the indications, as follows (1) without motion, but so arranged that full motion may be allowed later (2) permitting 10 to 15 degrees' or full dorsiflexion, yet preventing plantar flexion (3) permitting full plantar flexion but limiting dorsiflexion beyond a right angle.

Many excellent mechanical devices have been invented to meet the above requirements. Those which are simplest and most durable are preferable, particularly for long periods of use

T-Straps

Straps or pads are employed about the ankle to prevent lateral deviations of the foot and ankle by exerting a definite pull or pressure in one direction or the other There are several types of straps, the most efficient and practical being the so-called varus and valgus T-straps. The varus strap is attached to the shoe with the perpendicular portion on the outer side, while the transverse portion passes about the ankle and the inner bar of the brace pulling the ankle inward and maintaining the foot in the valgus position. The valgus T-strap is exactly the reverse of the varus strap the perpendicular portion is so made as to provide an even pressure upon the inner surface of the ankle and hold the foot in the varus position.

THE KNEE

In affections of the knee, the most feasible and practical position for future function of the extremity should ankylosis take place is 150 degrees flexion. Usually, however complete extension is regarded as the position of choice since, in affections of the knee, there is a constant tendency toward flexion with external rotation and genu valgum or knock knee. This is particularly true of children. If not prevented the deformity may become fixed and materially impair function of the extremity

Casts

The most efficient means of immobilizing the knee is provided by a plaster cast. This should be of ample length too often, immobilization is attempted by a cast which is too short and therefore fails in its purpose If the patient is excessively obese, the cast must include the hip extending from the toes to just above the crest of the ilium Generally however a cast which extends from the toes to the groin is sufficient. The patella and bony prominences must be well padded.

When weight bearing is permissible, the cast should extend from just above the ankle to the groin. To prevent the cast from slipping downward, strips of adhesive two inches in width should be attached to the skin of the

thigh and leg the lower ends being left free for six inches. Stockinet is placed over the limb from the ankle to the groin the padding is applied, and the ends of the adhesive are turned back and incorporated into the cast with the plaster bandage

Splints

Splints should be constructed to meet the requirements of the individual patient, although stocks of various sizes may be kept on hand and each splint trimmed to the proper length and adjusted as necessary

There are many types of posterior splints in current use for immobilization of the knee only three types, however, which are routinely employed, will be described (1) the short knee splint, extending from just above the ankle to the gluteal fold, (2) the long knee splint which includes the foot and (3) the gutter splint The short knee splint consists of a trough like thigh piece and a calf piece of aluminum which conform to the shape of the posterior aspect of the normal thigh and calf and are connected by brads to two steel bars, thus giving firm posterior and partial lateral support. The long knee splint is made by continuing the lateral bar below the heel, forming a loop to which a foot piece is attached by brads at the normal angle of abduction, as described for ankle splints. The ankle and knee joints are efficiently supported by the lateral bars. Since the bars also permit changes in alignment, the splint may be adjusted to the contour of the patient's limb The splint is padded with sheet wadding, particularly at the upper and lower edges of the thigh and leg pieces. The lateral bars should not touch the skin, and therefore should not require padding The splint is applied to the extremity without undue pressure at any point, and is maintained in position by four strips of adhesive which encircle the limb and splint. When the foot piece is employed two strips of adhesive are also passed about the foot and splint A roller bandage of gauze canton flannel, or muslin is placed around the entire limb and splint

The simple gutter splint extends from the gluteal fold to just above the ankle. For partial support, however the splint may be shorter Aluminum curved to fit the shape of the thigh and calf, is employed for this apparatus.

Thomas Splint.—The knee splint devised by H. O Thomas, being suitable for use in many affections of the leg thigh, ankle, knee and hip might well be termed the universal splint for the lower extremity Originally intended to maintain traction on the knee, the Thomas splint has been variously modified to fulfill a number of purposes i e., fixation and fixed traction during the patient's confinement to bed fixation and stilting with and without traction, for walking and, by the addition of lateral and anterior straps, correction of deformity The three types of Thomas splint in most popular use will be described (1) the recumbency splint, with or without traction (2) the ambulatory splint with stilting with or without traction and (3) the ambulatory splint for partial stilting with fixation.

The Thomas splint as originally designed consists of a ring which passes around the upper extremity of the thigh and an inner and outer rod attached vertically to the ring and connected below by a cross bar The ring is made of a cylindrical steel rod while the vertical rods may be of either cylindrical or flat steel The ring extends above the greater trochanter over

the anterior aspect of the thigh passes below Poupart's ligament, and closely conforms to the perineum the gluteal fold, and the tuberosity of the ischium posteriorly The circumference of the ring is made from a measurement of the thigh at the junction with the trunk, an additional two inches being allowed for padding The outer bar is measured from a point above the greater trochanter and the inner bar from the perineum both extend four inches below the heel, following the general shape of the extremity, and are joined at the lower end by a bar one inch broader than the transverse diameter of the

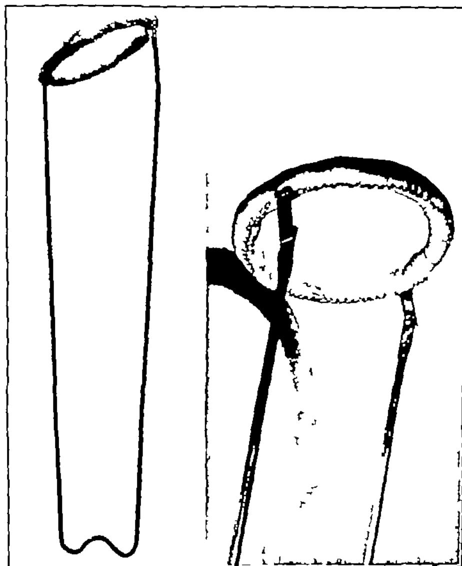


Fig. 12.—Thomas splint for lower extremity and modified Thomas splint with hinge for upper extremity

ankle joint. If preferred one continuous steel rod may be attached to the ring and bent to the proper shape. The ring is well padded with felt and covered with either a cotton flannel bandage or leather To provide additional support posteriorly slings of heavy cloth are stitched or pinned to the rods.

The leg is prepared by washing with soap and water shaving and sponging with alcohol Strips of adhesive are attached to the inner and outer aspects of the leg from a point just below the knee, as for Buck's extension,

and are allowed to extend twelve to eighteen inches below the foot The loose ends of the adhesive are rolled into heavy cords as one would roll a cigaret

In applying the splint the foot is passed through the ring and the ring is pressed upward to rest upon the perineum the tuberosity of the ischium and above the greater trochanter The free ends of the adhesive strips are then tied to the terminal bar and traction is exerted to the desired degree A cloth or leather legging to which lateral straps are stitched may be used instead of adhesive should the skin become irritated Slings of outing flannel are passed behind the leg and thigh around the inner and outer bars, and pinned A bandage is then applied to the splint and limb thus retaining the splint snugly in position and adding to the comfort of the patient A foot piece should be attached to the lateral bars to hold the foot at a right angle to the leg otherwise the foot must be dorsiflexed at least three times a day to prevent contracture of the tendo achillis and equinus deformity

The splint for walking with stilting is of the same proportions as that for recumbency The terminal bar may be broader and covered with leather to facilitate walking When stilting with fixation is desired, a leather strap is fastened to the heel of the shoe and the terminal bar to retain the foot at a right angle to the extremity

Every physician who is called upon to treat injuries or affections of the lower extremities should thoroughly understand the application of a Thomas splint and should keep in stock three sizes to be used in an emergency as follows (1) For children from four to eight years of age, the circumference of the ring should be 15 inches, the outer bar 25 inches, the inner bar 23 inches, and the terminal bar 3 inches (2) for children eight to fourteen years of age the circumference of the ring should be 19 inches, the outer bar 30 inches the inner bar 28 inches, and the terminal bar 3½ inches and (3) for those above fourteen years, the circumference of the ring should be 22½ inches, the outer bar 39 inches, the inner bar 36 inches, and the terminal bar 4 inches. These splints are not only a convenience to the physician but also serve to prevent shock and reduce mortality after severe injuries of the extremities, and to permit safe transportation of the patient.

Corrective Splint (Campbell Mitchner)—Flexion deformity of the knee may be corrected gradually by a short splint based upon the Sinclair modification of the Thomas splint. This apparatus permits regulation of extension or flexion of the knee by means of a turnbuckle inserted into inner and outer bars. The tendency to subluxation of the tibia on extension of the contracted knee is prevented by a hinged support to the calf of the leg The hinge is controlled by a set screw which makes direct pressure upon the calf and indirectly upon the upper extremity of the tibia thus preventing any backward displacement of the tibia. Traction is exerted on the leg by adhesive strips fastened to the cross bar of the splint (Fig 19)

Corrective Casts—Flexion contracture of the knee may be gradually corrected by plaster casts.

A long leg plaster cast which has been well padded over the heel, tendo achillis, malleoli, crest of the tibia and the patella is applied from groin to toes. Having set sufficiently the cast is partially divided around the knee, a

shelf of plaster from the thigh portion being allowed to project over the patella. Hinges may or may not be incorporated in the cast If so the center of the hinge and the knee should coincide. A steel upright and turnbuckle are then applied and correction is instituted as soon as the cast dries.

If hinges are omitted, a shelf of plaster is left just proximal to the patella and a piece of copper wire is embedded in the cast to prevent the plaster hinge from telescoping Steel uprights are then incorporated in the cast, as above described, or blocks of wood of increasingly large size may be inserted into the opening at appropriate intervals to straighten the knee.

Correction should be gradual, being limited by the tolerance of the patient Close observation is necessary for the early detection of complications, such as pressure sores, vascular and nervous disorders, and posterior subluxation of the knee.

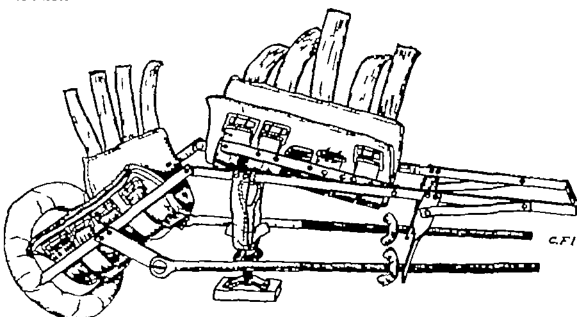


Fig. 19.—Campbell-Mitchner corrective splint for flexion contracture of knee.

Braces

The Thomas splint for walking with partial weight bearing may be attached to the shoe by means of a steel stirrup with a movable joint at the ankle or preferably by a caliper joint. In the latter the rods terminate below in a pair of calipers which fit into a tunnel of steel through the heel of the shoe. The tunnel should be placed obliquely from without inward, to permit normal abduction of the foot Adjustment of the splint for partial weight bearing is greatly facilitated by a turnbuckle with a lock-nut on both bars below the ring

Braces now in common use are constructed on the same principles, usually with a joint at the knee and ankle. The two lateral bars for the leg and two lateral thigh bars are joined posteriorly by padded semicircular metal bands which conform to the contours of the leg and thigh Leather cuffs are laced in front to hold the apparatus in position When complete fixation is desired, a leather corset, laced in front, and extending from the ankle to the groin, may be fitted. For partial weight-bearing a Thomas ring is attached to the proximal end of the thigh bars otherwise the brace extends as high on the thigh

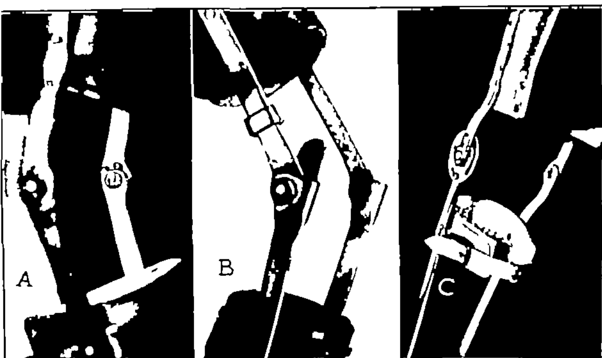


Fig. 20.—Joints for knee braces. *A*, Stop joint prevents hyperextension yet allows full range of flexion. *B*, Drop ring catch may be locked in extension for walking or released for flexion on sitting. *C*, Control dial joint may be regulated gradually from complete rigidity to full range of motion.

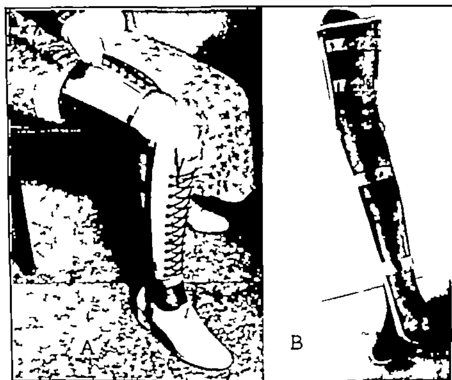


Fig. 21.—*A*, Leather lacer brace from ankle to knee, with free motion joints at ankle and knee. *B*, Leather lacer brace from groin to toes, reinforced by steel bars. Motion may be permitted at knee when indicated, by removal of brad from metal joint and removal of section of leather which encircles knee.

as is commensurate with comfort. Other than these features, the brace is varied according to the requirements of the individual case, particularly as to the type of joints at the knee and ankle

If the brace is to be worn constantly a caliper attachment permits removal of the shoe and the application of a foot plate at night to prevent equinus deformity At the knee, motion may be totally restricted or full motion may be allowed yet hyperextension prevented by a "stop joint" by means of a "drop ring catch the joint may be locked in extension for walking or released for flexion on sitting A control dial joint may be adjusted to allow a gradual increase in the range of motion (Figs 20 and 21)

Cage Knee Brace.—A short brace known as the cage knee brace, is suitable when less complete fixation will suffice This apparatus consists of steel bars which extend from the junction of the upper and middle thirds of the leg to the center of the thigh and are connected by metal bands at their upper and lower ends opposite the knee is a movable joint, which can be held rigid by a screw or brad. A leather lacing encloses the calf below and the thigh above. If the contour of the limb prevents the brace from fitting snugly and the brace slips downward, the steel bar on the inner aspect may be attached to the shoe by a steel stirrup in the heel, and a joint may be placed at the ankle.

Bandages

Following many procedures upon the knee, fixation by a cast or brace is unnecessary yet some support is desirable For such purposes, a heavy track" bandage six inches wide and five yards long (similar to those used for binding the ankles of horses), as suggested by F D Dickson, serves admirably Various types of elastic or semielastic bandages may also be utilized. Elastic knee caps with light metal hinges have been found effective.

Skin Traction

Buck s Extension.—*This form of apparatus is commonly employed in* affections of the knee to correct mild deformities and relieve pain from muscle spasm. The method of applying Buck s extension to the knee is similar to that described for the hip (p 46), with the following exception Adhesive strips are attached to the inner and outer aspects of the leg below the knee weights are added beginning with four pounds and increasing as indicated

Skeletal Traction

Skeletal traction for fractures of both bones of the leg or for fracture of the tibia involving the knee is established by a wire inserted transversely through the os calcis at a point in line with the internal malleolus, midway between the superior and inferior surfaces of the os calcis, or through the tibia just above the ankle

THE HIP

The most serviceable position for the ankylosed hip is 150 degrees flexion, neutral abduction and rotation. Since there is a tendency to malposition in flexion however complete extension should be maintained during the acute stage of all affections of this joint.

Casts

Casts for immobilization of the hip may extend (1) from the nipple line to the toes on the affected side (the long single spica) (2) from the crests of the ilia to the knee (the short single spica) (3) from the nipple line to the toes on the affected side and to the knee on the opposite extremity or (4) from the nipple line to the toes on both sides (the double spica)

For the proper application of a cast, the body and lower extremities must be elevated by supports beneath the shoulders, sacrum and feet to permit access to all sides of the body An orthopedic table is desirable The sacrum is raised upon a small triangular pedestal known as the hip rest Special attention is given to the padding of the bony prominences as the sacrum iliac crests, anterior aspects of the tibiae the malleoli and the heels. In applying the cast, the bandages should be carried well over the anterior and posterior aspects of the hip joint and plaster reinforcements placed over the points of greatest strain otherwise the cast may be expected to break As consolidation takes place the plaster should be carefully molded to the crests of the ilia When both legs are included a wooden bar must be incorporated between the thighs to prevent breaking of the cast by leverage

Casts and Splints to Prevent External Rotation of the Hip—When complete immobilization of the knee and hip is unnecessary a simple apparatus may be utilized to prevent external rotation contractures of the hip

With the heel and bony prominences of the ankle heavily padded a plaster cast is applied from the toes to just below the knee Before the plaster sets, a stick twelve inches in length is attached transversely to the posterior surface of the cast at the heel With the extremity slightly rotated internally the stick should be horizontal to the surface of the bed, the major portion of its length on the outer side of the foot.

A removable rotation splint is constructed by incorporating a steel bar on the posterior portion of the foot plate of a well padded short posterior night splint with straps and buckles.

Splints

Thomas Splint.—The Thomas splint, as previously described for the knee, may also be utilized for immobilizing the hip By placing a hinge joint at the knee, the extremity may be suspended with the knee and hip in any desired degree of flexion.

Hodgen Splint.—The Hodgen splint is similar to the ordinary Thomas splint, differing in the following respects At the knee the lateral bars are bent to permit immobilization of this joint in approximately 150 to 140 degrees flexion. For the purpose of suspension, rings are attached to the lateral bars of the splint near the ankle and between the hip and knee The Thomas ring is intact on the anterior half while posteriorly the two bars are connected by a leather strap This splint may be used solely for suspending the extremity in an elevated position with or without skin or skeletal traction. Should skeletal traction be desired the wire may be placed through the os calcis, upper portion of the tibia or lower portion of the femur The lower portion of the splint is fastened to the foot of the bed, to provide a stationary support

for the extremity In addition the splint may be utilized for traction purposes, according to the original description of Hodgen, or following the principles of a Russell traction.

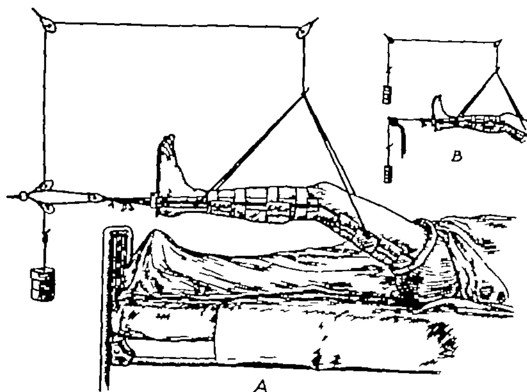


Fig. 22.—Hodgen splint. A Leg supported in Hodgen splint with Russell traction. B Modified Russell traction.

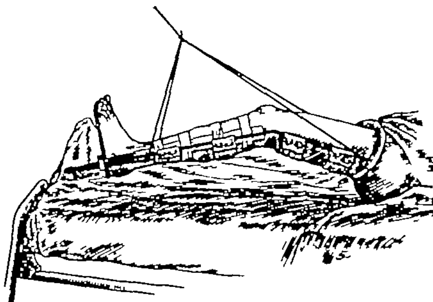


Fig. 23.—Lower extremity suspended in splint, according to original description of Hodgen.

Thomas Splint With Pearson Leg Piece.—The Pearson leg piece is attached to the Thomas splint by special clasps built into the piece proper with this attachment active and passive mobilization of the knee may be instituted as soon as feasible. The apparatus is widely used for the traction suspension treatment of fractures of the femoral shaft

Convalescent Splint.—The convalescent hip splint is a modification of the original Thomas hip splint This apparatus is constructed upon a steel bar which extends posteriorly from the scapula to the foot on the affected side, conforming to the contour of the posterior aspect of the chest loins buttocks, thigh and calf, and terminates in a sole plate To this bar are attached steel bands with straps which encircle the chest, the pelvis below the iliac crests, and the upper and lower thirds of the thigh and calf, and are fastened with buckles. A sole plate prevents rotation of the lower extremity In bilateral affections, a double splint of this type may be applied

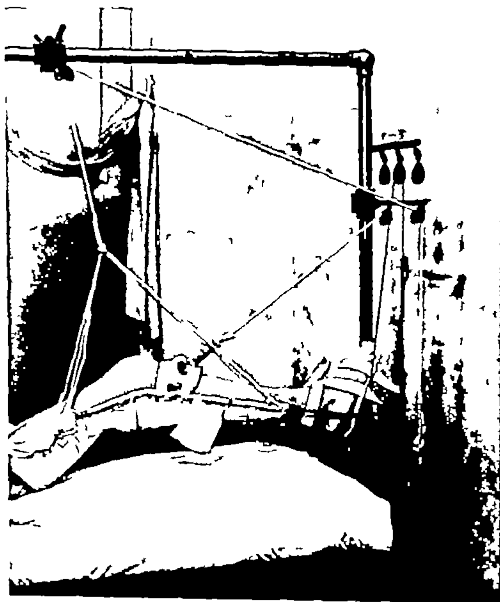


Fig 24.—Hodgen splint rigged for skeletal traction.

Corrective Splint.—Apparatus similar to that described for contractures of the knee may also effectually correct those of the hip Here contractures usually are observed in three directions flexion, abduction or adduction, and internal or external rotation. The apparatus, therefore must be so constructed to apply gradual corrective force in these planes. Since this apparatus is too cumbersome to be practicable correction usually is secured by traction

Fig 23.—Extremity suspended in a Thomas splint, with Pearson leg piece for skeletal traction.

Fig 24.—Unilateral and bilateral convalescent hip splints.

Braces

The Thomas caliper brace is useful as a convalescent measure in many affections of the hip joint when only partial weight bearing is allowed. *The abduction hip brace of Bradford*, which is a modification of the Thomas knee splint, is also valuable. The anterior half of the perineal ring is omitted; the other half is continued upward over the pubic bone and genitals, then downward to the opposite groin and along the groin to the middle of the

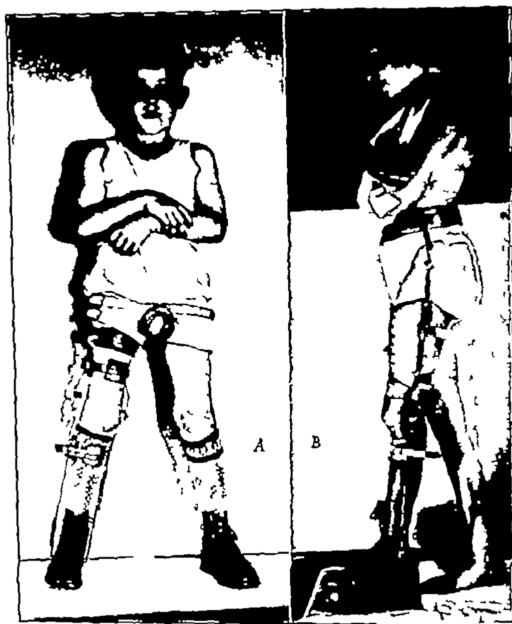


Fig 27.—*A*, Bradford abduction hip brace. *B*, Pelvic band, freely movable hip, drop ring catch at knee, and limited motion ankle joint with three-inch balsa wood elevation.

gluteal fold. The terminal bars are passed through a tunnel in the heel of the shoe. Joints may be incorporated at the knee to permit flexion when the patient is sitting, yet hold the knee rigid on walking. When a fair degree of immobilization of the hip is desired, a steel bar is continued up the side of the chest and held in place by semicircular padded bands and straps around the chest and pelvis. A joint is attached to the bar at the hip; this may be held rigid when weight-bearing is begun. For maintenance of abduction, an in

verted V piece with a joint at its apex is fastened by one arm to the thigh bar of the affected side. The opposite arm is fixed to the una thigh by straps.

When weight bearing and absolute immobilization of the hip are de a leather lacer brace, reinforced by steel bars, is constructed to encase th thigh, and leg from the nipple line to the ankle. Usually, the joint incorp at the knee is held rigid in the beginning when motion is permissible, the is cut out at the knee and the joint unlocked A caliper joint at the ank mits the attachment of a shoe or sole plate

Skin Traction

Buck s Extension.—Partial immobilization correction of mild co tures, and relief of pain from muscular spasm are often accomplish traction with Buck s extension. This measure is one of the simplest an valuable, and is applicable to a larger number of conditions than any oth appliance.

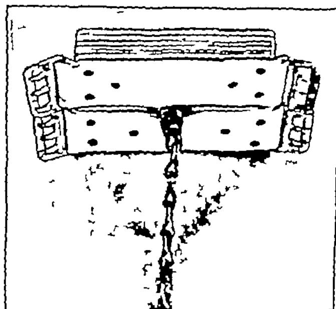


Fig. 21.—Spreader block for Buck's extension. Buckles allow easy adjustment of dista tween sole of foot and block.

The patient must remain constantly in the reclining position, at no being allowed to assume the sitting posture. The entire body should be ported on a firm surface either a Bradford frame may be used, or board be placed beneath the mattress to prevent sagging of the bed from the wei the pelvis.

After the limb has been shaved, strips of adhesive plaster two inches in are applied longitudinally to the inner and outer aspects of the extremit tending upward to just below the hip and distally eight inches beyond th of the foot. These are held in place by circular strips of adhesive whi turn, are covered with a cotton elastic bandage. The ends of the adhesive are folded on themselves and split down the center to form two tails. To pr undue pressure on the inner and outer malleoli a spreader block is atta being constructed as follows Two canvas straps, approximately six i

long with a buckle at each end, are tacked to a block of wood three to four inches long which has a hole in its center A rope is drawn through the hole and knotted and the block is then well padded The two tails of the adhesive strips on each side of the malleoli are fastened to the spreader block passing through the four buckles this facilitates adjustment of the spreader block to the desired distance from the sole of the foot and also maintains equal tension on the inner and outer straps. The block should be sufficiently close to the sole to prevent the foot from dropping into equinus. A pulley is attached to the foot of the bed *in a direct line* with the affected limb and the free end of the rope is passed through the pulley Weights are applied beginning as a rule, with four pounds, and gradually increasing to ten or fifteen pounds, as indicated



Fig. 23—Balanced traction for gradual correction of bilateral flexion contractures of knees and hips.

Extension is begun in the angle of deformity when deformity is present If the hip or knee is flexed at a right angle, the patient is placed on a firm bed and a support of proper height is inserted beneath the knee Balanced traction may be employed a sling under the knee providing traction in an upward direction. As the knee and hip extend the limb is lowered until full extension is secured. Traction must always be in a direct line with the leg and adjusted as the deformity is corrected

When no deformity is present, Buck's extension may be utilized to allay muscle spasm *Traction is instituted with the knee in extension and the hip in the neutral position.*

Skeletal Traction

Skeletal traction wherein pull is exerted directly upon the bones, is much more effective and comfortable than skin traction considerably more traction may be secured in this manner than is possible with the ordinary methods of skin traction The obvious disadvantage of the procedure is the danger of infection around the pins or wires. The number and severity of infections vary according to the size of the wire or pin employed and the type of metal of which they are constructed. With rare exceptions, we prefer a rust less steel 1 mm Kirschner wire for traction as this renders danger from infection practically negligible. The insertion of the wire should not be taken lightly, even though the procedure is a simple one, as infection from a wire can be equally as serious as that from a major operation. Routine aseptic surgical technic, with adequate draping should be carried out invariably

For affections of the lower third of the femur the wire is inserted by a special drill through the anterior portion of the tibia at the level of the tibial tubercle. For lesions of the upper two-thirds of the femur or for the hip the wire is inserted through the lower metaphyseal region of the femur midway between the anterior and posterior surfaces. In children, the wire should be well proximal to the epiphysis

After insertion of the wire, small incisions are made distally from the apertures on the skin, to prevent tension on the skin when traction is begun. The incisions are dressed with small circular sponges placed over the ends of the wires and thoroughly saturated with collodion These dressings are not disturbed until the wires are removed. To preclude danger of infection from undue to-and fro excursion of the wire within the bone, small cork stoppers are placed between the skin and the traction loops. As a further precaution, the traction should be exerted on the loop in a direct line with the leg the wire being as near a right angle to the transverse axis of the leg as possible. This in itself aids materially in prevention of to-and fro excursion

Fixed Traction

Fixed traction has the advantage of permitting the patient to be turned as often as he desires, thus practically obviating the danger of decubital ulcers.

The Hoke-Martin "plaster traction apparatus affords an excellent means of fixed traction. This apparatus consists of two longitudinal bars joined at the distal end by a transverse rod and a ratchet windlass two inches from the distal end of the rod. The lateral bars conform to the contour of the ex tremity

Technic.—Strips of adhesive two inches in width are placed on the thigh as for a Buck's extension, the folded ends of the adhesive extending at least eight inches beyond the heel Padding is then wound about the extremity as for a double spica cast, from the nipple line to the toes on the normal side and to the knee or ankle on the affected side. When the cast extends to the ankle, cotton or cellulose cotton is added to the usual padding to allow for excursion of the leg inside the cast. Traction apparatus is incorporated in the cast on the affected extremity The ends of the adhesive strips which extend beyond the heel are engaged on the points of the ratchet windlass and tightened by turning the windlass with a key Countertraction is exerted by the plaster

cast on the sole of the opposite foot Traction is increased daily until the desired position is obtained This is similar in principle to so-called well leg traction

For traction with the knee and hip in flexion, the apparatus is incorporated in the cast in line with the femur The leg is supported in a Pierson attachment with a foot plate to maintain the foot at a right angle. Either skin or skeletal traction may be used.

THE SPINE

Immobilization of each region of the spine presents a different mechanical problem Certain principles however, are applicable to the entire spine

In destructive or traumatic affections involving the bodies of the vertebrae the spine should be immobilized in hyperextension, as loss in continuity of bone tends to cause flexion of the spine by gravity or muscular pull, resulting in kyphosis. In affections of the upper third of the spine, the weight of the head is an important factor in the development of deformity and in exacerbating the process, apparatus for the purpose of fixation, therefore, must also relieve the spine of this weight In the lower lumbar spine complete fixation is not possible unless one or both hips are included in the apparatus. In the presence of a progressive destructive lesion, deformity is prevented by immobilization of the spine with the patient in the supine position

Sacroiliac Belts

Many types of belts have been devised, with numerous minor variations. A description of one will suffice This type of support is inadequate except for mild affections of the low back region for women properly fitted surgical garments or corsets, are particularly satisfactory

A simple belt, with removable and adjustable pads extending from the crest of the ilium to the upper extremity of the coccyx, is made of canvas or some other type of resistant cloth. Metal stays and leather straps are incorporated to prevent wrinkling and shoe string lacings anteriorly and posteriorly and on each side permit adjustment of the apparatus for compression of the pelvis. Perineal bands, passed through rubber tubing will prevent upward displacement of the belt. For women suspension garters may be attached to the belt and fastened below to the hose.

Casts

Plaster of Paris casts have the advantage of affording continuous fixation of the spine For physical therapy and heliotherapy the cast may be bivalved and the anterior and posterior halves used alternately for support.

As a temporary measure, or for the purpose of transportation, a plaster bed may be made which conforms closely to the contour of the spine from the superior aspect of the head to the tip of the sacrum. The patient is placed prone upon a table and a strip of outing cloth or other padding is cut to the desired dimensions and spread over the back. The plaster of Paris bandages are folded, first in a longitudinal direction then transversely covering the posterior half of the body After setting the cast is removed all rough edges are trimmed, the padding adjusted and held in place by adhesive plaster the cast is then reapplied and bound to the body by adhesive strips and bandages.

When complete rest is desired, the entire spine is immobilized This may be effected by a cast which includes the thighs below and the head above. Fixation of limited regions may be accomplished by casts of the three following types, all of which may be modified as occasion demands.

1. Plaster jacket for immobilization of the midregion of the spine (from the ninth dorsal to the second lumbar vertebrae)

2. Plaster cast for immobilization of the spine above the ninth dorsal vertebra including the chin and occiput or if necessary, practically all of the head.

3 Plaster cast for immobilization of the lower spine, beginning above at the nipple line and including one or both hips.

An increase in body weight may cause the cast to become uncomfortable, necessitating its removal. More frequently however removal is required because of atrophy of fat beneath the cast and consequent loss of the efficiency of the support Care should be taken to prevent foreign articles from falling under the cast, as they may cause discomfort and pressure. While the patient is in the cast, a close watch should be kept for decubital ulcers. A cast should be retained no longer than three months at the latest. One patient, however insisted upon retaining a cast for three and one-half years no apparent deleterious effects on the skin were observed.

There are several methods of applying casts for lesions of the spine (1) For applying casts from the nipple line to one or both knees a routine fracture table is used, (2) for jacket casts, or casts which extend from the iliac crest and include the chin and occiput, the Sayre suspension Hibbs frame or a modification of the latter is most efficient (3) for applying hyperextension casts, which extend, as a rule, from well above the nipple line to the iliac crest or to one or both knees, the canvas sling canvas hammock, O'Donoghue jack, Goldthwait frame or portable hyperextension frame is appropriate. Since special apparatus is not always available, improvised supports for the application of body casts will also be described.

Before application of the cast by any method, the skin of the patient is prepared and the region is covered with stockinet. Being elastic, the stockinet conforms closely to the body Scratchers, or long strips of flannel, may be inserted beneath the stockinet to add to the comfort of the patient. For jacket casts, the iliac crests, which act as a support, must be well padded with sheet wadding outing flannel, or felt. The chin and occiput are similarly padded when the cast is to include this area.

Sayre Suspension.—By the Sayre suspension method traction is exerted on the head, separating the vertebrae and straightening the spine. For jacket casts, a leather halter which conforms to the chin and occiput is employed. Straps are placed on each side and fastened above to a crossbar A block and tackle are attached to the center of the crossbar and suspended from the ceiling or some other point overhead in orthopedic clinics and hospitals where casts are frequently applied, a rectangular pipe or wooden frame is used. The halter is adjusted to the head of the patient and traction is exerted through the block and tackle until the heels are elevated and only the balls of the feet rest upon the floor The end of the rope is attached to a cleat at some convenient point. The upper extremities are abducted at a right angle to the body and the patient

lightly grasps the lateral posts or other fixed objects. Plaster of Paris bandages are then applied in layers to a thickness of one-fourth to three-eighths inch, these should be molded over the well padded crests of the ilia and should otherwise conform to the contours of the body After solidification the halter is removed and the cast trimmed Anteriorly, the upper edge of the cast should extend to the sternal notch, curving under each axilla to permit free use of the upper extremities. Below, anteriorly, the cast is trimmed to the level of the symphysis pubis and concavities are cut on each side to permit flexion of the thighs in the sitting position. Posteriorly, the cast is trimmed above on a level with or just below the spines of the scapulae, and below to the top of the gluteal cleft The stockinet at the upper and lower ends is turned outward and fixed by additional bandages, thus retaining the padding in situ and protecting the skin from the rough edges of the cast.



Fig. 30 —Cast for support of upper dorsal or cervical spine extends from chin and occiput to below crests of ilia. Cast must be well padded over bony prominences.

For adults, if respiration is difficult or pressure symptoms are present after eating an abdominal window six to eight inches wide may be cut in the cast. Windows are often required in the first casts, though unnecessary in those subsequently applied

For support to the upper dorsal or cervical portion of the spine shirting or stockinet is applied to include the head, holes being cut for the eyes, nose, and mouth. The patient is suspended by a muslin sling or halter The first

other, suspending the spine between A sling of canvas or heavy muslin from three to five inches in width is inserted beneath the affected region and traction is exerted through the block and tackle until the proper degree of hyperextension is secured The padding and cast are then applied After consolidation of the cast, the sling is cut on both sides at the surface of the cast and further plaster bandages are laid over the defect If the cast is to be applied about the shoulders, neck, and head the head may be supported by a second sling beneath the occiput If the hips must be included in the cast, a hip rest may be substituted for the box which supports the thighs as for the application of a plaster spica A special table considerably expedites this procedure (Fig 31)

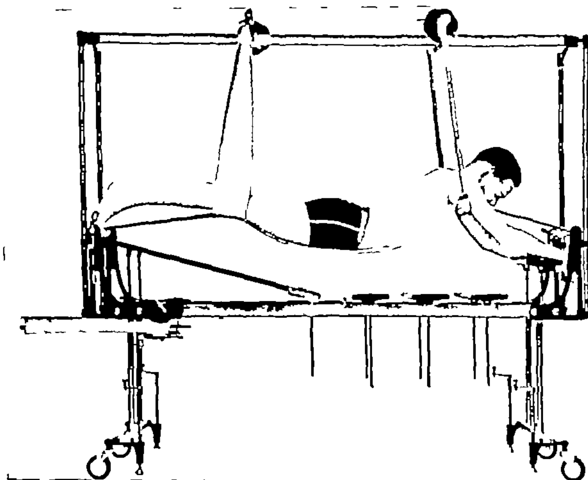


Fig. 32.—Hammock hyperextension of spine on Bell fracture table. (Courtesy of Mr Gilbert Hyde Chick.)

Hammock.—For the application of a cast by the hammock method, a rectangular pipe frame or special table is necessary A hammock of canvas or heavy muslin is attached at one end to the crossbar of the frame and at the other end to a steel rod. Ropes are fastened to the rod and controlled below by a pulley and ratchet The patient is placed face downward upon the hammock and tension is released by the ratchet until the desired degree of hyperextension is secured. The cast is then applied about both hammock and patient. After consolidation of the plaster the hammock is removed and the cast trimmed above and below (Fig 32)

O'Donoghue Jack.—The O'Donoghue jack is used principally for the reduction of compression fractures of the dorsolumbar region This apparatus

consists of an ordinary automobile jack with a detachable metal platform six inches in length and four inches in width. The platform is padded with heavy felt and the patient placed across it in the supine position, the fracture being immediately over the jack. The shoulders are supported on the edge of a fracture table and the legs tied to the foot pieces (or two boxes on a flat surface will suffice to support the hips and shoulders). As the jack is raised, the spine is hyperextended to the desired degree.

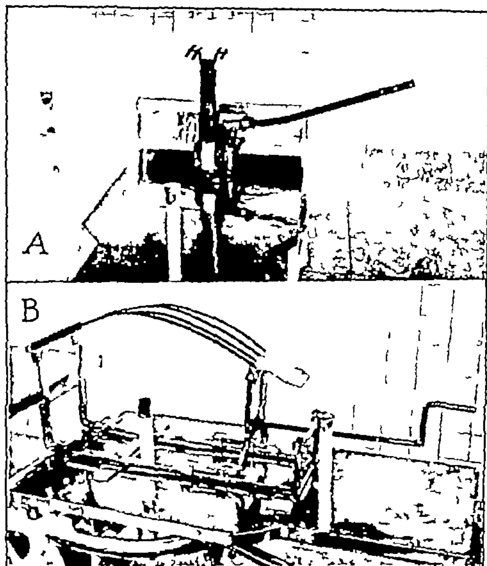


Fig. 31.—Portable apparatus for hyperextension of spine. *A*, O'Donoghue jack. *B*, Modification of Goldthwait hyperextension frame.

After the cast is applied the platform is removed from the jack, remaining within the cast. The patient is then turned on his face, the platform withdrawn from the cast through a window and the defect filled with additional plaster.

Goldthwait Frame.—Many years ago Goldthwait described an apparatus for applying hyperextension casts. A rectangular gas pipe frame was placed between two saw horses and two adjustable steel slings were suspended from the side bars in the center of the frame. Two prongs were fixed in a vertical

position to the center of each sling, and malleable steel bars of proper length were in turn suspended from these prongs, providing support for the patient's spine in the desired degree of hyperextension Goldthwait later devised a less cumbersome apparatus which stood on an ordinary table, the frame being omitted

Portable Hyperextension Frame.—Many improvements, such as stabilization of the malleable rods which are adjusted to the desired degree of hyperextension by a screw attachment, have since been added to the Goldthwait apparatus. We are unable to establish priority for the invention of these features. No originality is claimed for the hyperextension frame illustrated in Fig 33*B*

The Bell fracture table is particularly adaptable to the application of hyperextension casts by either the sling or hammock method The cast may be applied with the patient suspended in the prone position on a canvas hammock, or hyperextended in the supine position on a sling and hammock. Hyperextension is secured by a transverse steel rod sling at the apex of the desired curve the rod being attached by muslin strips to a windlass above (Figs 31 and 32)

Watson-Jones Two Table Postural Reduction—The conscious patient is laid between two tables, the front table being 10 to 12 inches higher than the back table The upper table is clear of the chest, while the lower table extends to the upper thighs. The trunk is entirely unsupported, the patient supporting himself on the front table by his abducted arms. The plaster cast is applied with the patient in this position The weight of the body and the additional pressure of rubbing the successive layers of the cast are sufficient to effect a reduction of the fracture.

Corrective Jackets.—The various types of plaster of Paris jackets employed for correction of deformities of the spine are described in detail in the section on Scoliosis.

Braces

Removable jackets of leather or celluloid may be made over a plaster model of the patient's body For making the leather jacket a piece of leather of suitable dimension is soaked in hot water stretched over the torso and, when completely dry, is removed This is lined with chamois skin and reinforced with steel bars about the pelvis and up the back Hooks are placed along the anterior margins for lacing Fenestra in the leather add to the comfort of the patient in warm climates or during the summer

Celluloid jackets are made by placing several thicknesses of stockinet over a plaster torso and painting each with a solution of cellulose acetate The solution should be fresh and of the consistency of thick syrup or molasses. Tincture of ferric chloride may be added to the solution to make the jacket noninflammable. This type of brace gives excellent support but may cause irritation of the skin in warm climates.

The majority of the spinal braces in current use are modifications of the original Taylor brace which consists of two parallel steel bars, one on each side of the spinal column, conforming to the contour of the back, fastened at the lower end to a pelvic band and above to a short crossbar at the level

of the spines of the scapulae Straps attached to the upper ends of the upright bars pass over the shoulders and backward beneath the arms to the point of origin A canvas apron covering the chest and abdomen is fastened to the brace by straps and buckles at different levels anteriorly thus holding the brace

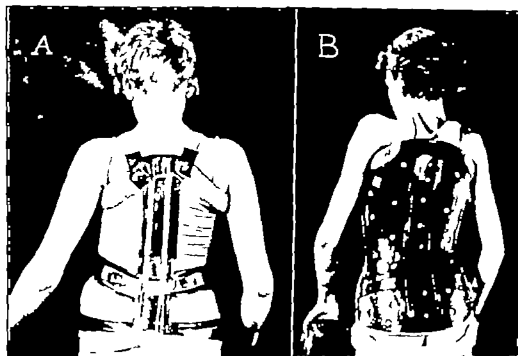


Fig 34 —*A* Steindler back brace. *B* Leather lacer corset reinforced by steel bars curved to maintain correction of scoliosis.

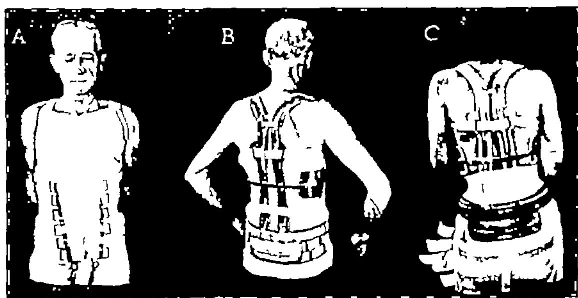


Fig. 35 —*A* and *B* modified long Taylor spine brace. *C* Long Taylor spine brace with sacroiliac attachments.

in close approximation to the body Lateral support may be added by steel plates which conform to the lateral aspect of the thorax and are connected to the upright bars by another transverse steel bar The pelvic band should fit snugly below the crests of the ilia and should be fastened anteriorly by buckles.

In affections of the upper dorsal or cervical spine the head is immobilized by an apparatus fastened by a steel rod to the upper transverse bar of the spinal brace. This apparatus consists of a steel plate which supports the occiput, and a strap which passes around the forehead to hold the head in position The weight of the head may be lifted from the spine by a circular aluminum attachment which conforms to the chin and occiput and is connected to the brace below by a longitudinal bar The attachment is adjustable, insuring constant support of the head, the chin piece is so constructed as to be removable. With this measure the weight of the head is borne largely by the pelvis through the vertical bars and the pelvic band.

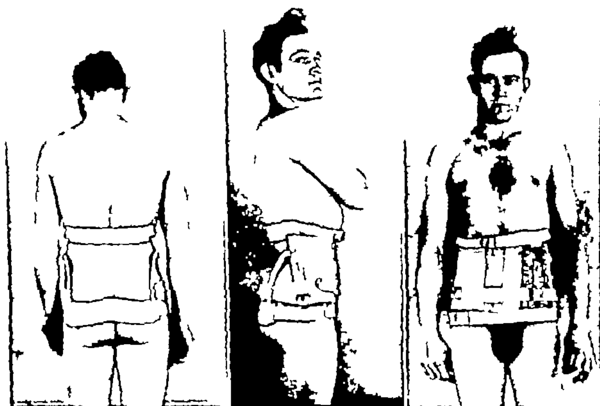


Fig 34.—Williams back brace.

In children, when complete fixation of the spine is desired, the head also must be immobilized and the brace prolonged below to incorporate both thighs. This is accomplished by two steel bars attached to the pelvic band and extended down the posterior aspect of each thigh to the knee. Two metal bands are fastened to each bar one at the gluteal fold and the other just above the knees, and are held in position by straps and buckles over the anterior aspect of the thigh Support is thus provided from the occiput to the knees. In destructive lesions, such as tuberculosis, the brace will maintain the maximum fixation and reduce deformity to a minimum.

For adults with affections of the lower lumbar or lumbosacral region a low back Taylor brace is made which extends only from the pelvis to the dorsolumbar region. A sacroiliac belt may be attached to the pelvic band and incorporated within the brace For the average low back affections, a light brace that covers a minimum of skin surface provides some degree of flexibility and relieves an

increased lumbar lordosis, is desirable. The Williams' back brace (Fig 36) fills these requisites admirably

A light and efficient jacket, such as the Knight or Steindler brace, is often employed as a convalescent measure in lateral curvature. The apparatus is made over a plaster torso Two bands of steel, one just above and one just below the crests of the ilia encircle the anterior superior spines, firmly gripping the pelvis. Two strong steel bars are placed up the back A cross band at the

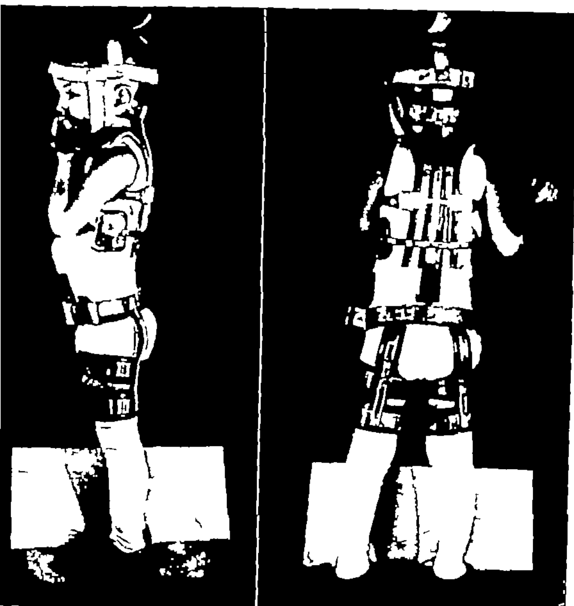


Fig 37 —Brace for complete fixation of entire spine, extending from head to knees. Used almost exclusively for tuberculosis of spine in children.

level of the spines of the scapula passes under the axillae supporting the arms the anterior part of the crutch is flattened out to exert pressure backward below the clavicle. In front steel bars extend down to the girdle and, to give the crutches further support, a flat steel stay is run from their center to the girdled band just above the iliac crests. Straps are placed anteriorly to hold the brace in position and, if desired, elastic bands may be attached to provide lateral pressure.

Bradford Frame—For maintaining the patient on a firm surface in the supine position the most efficient apparatus in common use is the rectangular gas pipe frame with canvas cover described by Bradford. This may be made by a plumber blacksmith, or anyone capable of using a Stilson wrench. For young children, pipe one-fourth inch in diameter is used and for adults, pipe one inch in diameter, four elbows of corresponding size are also necessary. The frame should be slightly wider than the patient's shoulders and the length should be twelve inches longer than the patient's height. For the average adult, the length should be approximately six and one-half feet, or that of the usual bed. Threads are cut by dies on each end of the pipe, in reverse directions at opposite ends, to conform to the threads in the elbows. All parts are

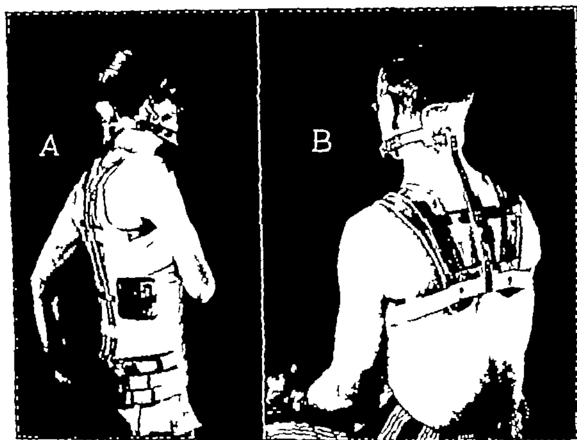


Fig. 33.—A, Long Taylor spine brace with attachment for support of cervical spine. B Cervical spine brace chin piece removable.

joined and tightly screwed together with a Stilson wrench. A heavy canvas cover is made, three-fourths the width of the frame and two inches less in length. Through eyelets one-eighth inch in diameter placed along the edges, the cover is laced to the frame with rope, giving a slightly elastic surface. A blanket is then placed over the frame and held in position by safety pins and a sheet is similarly applied. An oilcloth or rubber sheet is next laid over the midportion of the cover and this in turn is covered by a draw sheet. The cover is best made in three segments i.e. a long upper and a long lower portion and a narrow central portion. Unless the cover is thus divided, the old fashioned bed pan should be used; the modern douche pan necessitates raising the hips too high and defeats the purpose of immobilization and rest.

The frame may be supported at each end by wooden boxes, although the patient is much more comfortable if the frame lies directly on the bed. The

care of the patient is facilitated by a system of ropes and pulleys with a control ratchet at the foot of the bed which permits elevation of the frame with the patient.



Fig. 39.—*A* For minimal support, a Thomas collar *B* For more efficient fixation, a light cervical brace.

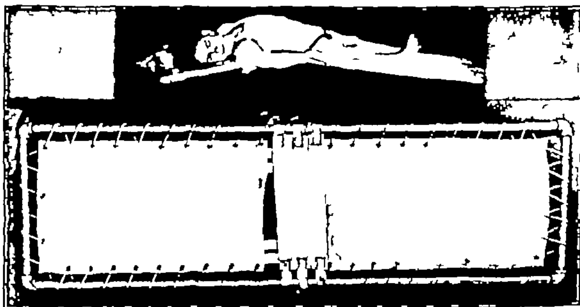


Fig. 40.—Bradford frame, and hyperextension Bradford frame with Carrell attachments.

Hyperextension of the spine may be secured by the use of strips of saddler's felt. These strips, which should be four inches in width for adults and proportionate widths for children, are inserted beneath the spine every few days until the desired degree of hyperextension is obtained. Or the frame may be

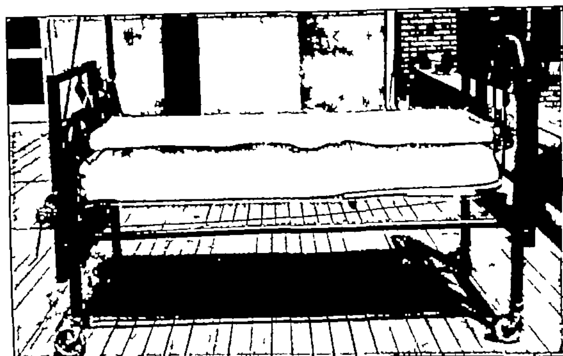


Fig. 41.—Use of bed pan facilitated by a system of ropes and pulleys with a control ratchet at foot of bed.



Fig 4[illegible].—Stryker turning frames hold patient firmly permitting one nurse to turn patient with little effort and with a minimum of discomfort. (Courtesy of Orthopedic Frame Co., Kalamazoo Mich.)

bent to the proper degree to form a convex surface, according to the method of Whitman Wallace attaches a hinge to the frame which permits its adjustment to the requirements of the individual case. The Rogers frame is similar in principle but more efficient

The patient upon a Bradford frame requires careful nursing, even supposedly well trained attendants must have constant supervision When incompetent nurses or members of the family are in attendance, they must be taught how to bathe and dress the patient. For the bath the patient, with the frame, is turned on the side onto a firm surface and the frame is then removed. Or the head shoulders, pelvis, and lower extremities may be supported and rotated with the trunk Unnecessary flexion and side bending of the spine must be prevented Frequent cleansing of the skin with alcohol and the application of dusting powder to the lower portions of the back and buttocks are necessary to prevent the formation of decubital ulcers.

Children or adults who turn in their sleep should be restrained by bands placed over the chest pelvis, and thighs. The simple restraining splint devised by Carrell which allows exposure for heliotherapy, is preferable Two iron rods are bent to conform accurately to the shoulders and thighs. The apparatus is attached to the upper end of the frame by means of a hinge, thence over the shoulders, along the sides of the chest and abdomen, and over the groin to a thumb screw attached to a crossbar on the frame just below the perineum.

The Stryker Turning Device.—This apparatus consists of two Bradford frames, one anterior and the other posterior which are connected by turning devices clamped on the ends of the bed. A portable frame with the turning device supported by a base which rests on the bed or on casters is also available. The frames are made of lightweight tubing covered with heavy canvas and properly padded For the standard hospital bed, they are 6 feet 3 inches long and for the portable unit, they are 6 feet 1 inch long A 6 inch opening at the center allows toilet service Attachments are provided for the support of the feet at right angles, and for the arms at the sides of the frame

The patient is placed on his back on the posterior frame each end of which is attached to the turning device. The anterior frame is placed over the patient, securely anchored to the posterior frame and locked in this position. A spring lock at the end is then released allowing the frames to revolve through an angle of 180 degrees at this point, the frames automatically lock leaving the patient face downward on the anterior frame In like manner the patient may be turned again from this position to the posterior frame.

Traction

Head traction, for affections of the upper portion of the spine, may be instituted by the Sayre halter A rope is tied to the center of the crossbar and passed through a pulley fastened to the bed or to the center of the upper crossbar of the frame. Weights are attached to the end of the rope and increased until muscular spasm is relieved Five pounds usually is sufficient, although ten pounds may be applied if indications demand. If the patient tends to slide upward, causing the bar to approximate the pulley and thus relieve traction, the head of the bed should be elevated.

Crutchfield tongs for skeletal traction on the cervical spine are used almost exclusively for fractures or fracture-dislocations. A description of these tongs and the method of their application will be found in the chapter on Fractures.

Should traction on the spine from below be required, weights may be applied to the legs by means of Buck's extension as described under appliances for the hip joint. The pulleys are attached to the lower crossbar of the frame or to the bed, in alignment with the lower extremities. Direct pelvic traction may be secured by means of a pelvic girdle and straps. Extension to the extremities, however generally is adequate.

THE UPPER EXTREMITY

In applying all aparatus for the upper extremity, except for lesions of the hand the fingers must remain sufficiently free to be doubled into a fist. *This is vitally important Active motion of the fingers should be practiced* at frequent intervals.

THE SHOULDER

The most serviceable position of the shoulder usually is 150 degrees flexion, slight internal rotation, and 135 degrees abduction. In affections of this joint the arm tends to become fixed in adduction immobilization, therefore, should be carried out with special attention toward prevention of this deformity

Casts

The shoulder may be maintained in any position desired by plaster of Paris casts of either of two types. The first type extends well over the iliac crests to insure firm support even then, in obese patients immobilization is not satisfactory as the cast rarely conforms snugly to the contour of the



Fig 45.—The hanging cast. For fractures of lower third of humerus, the forearm is maintained in a pronated position.

shoulder The second type encases only the upper extremity and thorax and is suspended from the opposite shoulder by a strap or band of plaster In either the elbow and wrist should also be immobilized, but the cast should not extend beyond the metacarpophalangeal joints, as motion of the fingers should be free.

The Hanging Cast.—This cast first described by Caldwell of Cincinnati in 1933 was designed for the treatment of fractures of the shaft of the humerus though it has also been used successfully for certain fractures of the humeral neck. In principle, the cast converts the forearm into a lever with the wrist as a fulcrum The force is exerted in the line of the humerus, while the necessary traction is supplied by the cast and the unsupported portion of the arm and fore arm

With the forearm flexed at a right angle the cast is applied from the wrist to the axilla A loop of wire is incorporated into the cast at the wrist for the suspending sling or if preferred, a plaster loop may be made to serve the same purpose To correct high abduction fractures of the humerus a pad is placed over the inner aspect of the arm In certain cases of fracture of the humeral neck with medial angulation, a pad is placed high in the axilla and fixed to the cast. Anterior bowing is corrected by shortening or lengthening of the suspending sling To prevent a cubitus varus a fracture of the lower portion of the shaft should be immobilized with the forearm in pronation.

Splints

For fixation of the shoulder and shaft of the humerus, a Thomas splint, or Sinclair modification thereof, will suffice as for the lower extremity, or the humerus may be bound to the chest wall by adhesive strips, the forearm being supported in a sling In the latter event a pad should first be placed in the axilla

The Campbell traction humerus splint consists of a large metal plate which fits the lateral aspect of the thorax, an upper arm piece extending from the axilla to the elbow and a forearm piece joined to the upper bar at a right angle and continuing to the middle of the palm. The elbow is thus flexed at 90 degrees and the wrist is held in the neutral position. These segments conform to the contour of the inner aspect of the arm and forearm and vary in width from one and one half to three inches according to the size of the arm. The splint is well padded, placed as high as possible in the axilla and slightly to the anterior aspect of the chest, and held in place by straps of webbing passed about the body and opposite shoulder and fastened to the thorax piece This portion of the splint is used as a convalescent support.

When firmer fixation or fixed traction is desired an attachment for straps is provided by a metal bar fastened to the inner surface of the arm piece and extending three or four inches beyond the elbow then upward at a right angle Adhesive strips are placed on the inner and outer aspects of the arm and allowed to extend six to eight inches below the elbow the strips are bound to the arm by loosely applied circular bands of adhesive. Reinforcements of adhesive secure the splint firmly in the axilla. The strips on the arm are then attached to the traction bar under tension The forearm is bound to the fore arm piece by adhesive and thus maintained in midposition as to rotation. A roller bandage of gauze or muslin is wrapped about the entire upper extremity

The arm, forearm and chest portions of the above described splint were devised by Henderson as a convalescent support following fractures of the upper end of the humerus. The portions for traction were added by Campbell Modifications have been made for injuries or abnormalities of the lower segments of the humerus, the elbow, and forearm The forearm piece may be attached to the arm piece so as to permit controlled rotation of the forearm or to fix the forearm in any desired position from extreme supination to extreme pronation.



Fig 46.—Plaster of Paris cast for immobilization of shoulder and shaft of humerus. *A* Cast extends to iliac crest. *B* Cast extends to lower margin of thorax and is suspended from opposite shoulder by a band of plaster

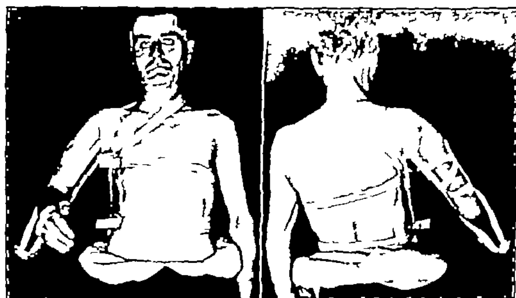


Fig. 47 —Campbell traction humerus splint.

A loop of wire may be fastened to the forearm piece and extended well below the hand to allow attachment of adhesive strips on the forearm for the purpose of traction. When the loop of wire is added a flange is affixed to the arm piece passing over the anterior aspect of the arm to permit a fulcrum for countertraction. By this means, traction is maintained while the patient walks about. If fixation only is necessary the traction bar is removed or omitted.

A modification of the Thomas splint, devised by Jones, consists of an upper ring with lateral bars which conform to the arm and forearm with the elbow flexed at a right angle, and are bent into loops beyond the elbow for the purpose of traction.

The airplane splint for maintaining abduction of the arm is constructed of heavy steel wire or bands curved to the contour of the thorax and upper extremity in the desired degree of abduction, which is generally 90 degrees Heavy muslin or canvas strips are fastened between the bars of the splint and the apparatus is secured to the body by straps or bandages.

Braces

Leather corsets which include the arm shoulder and chest are employed principally for fractures of the humerus as convalescent supports following open operations for malunion or nonunion Exact measurements are secured from a plaster model.

Traction

Fixed traction on the arm or shoulder usually is carried out satisfactorily by the traction humerus splint, described above If traction by weights is necessary the suspension apparatus described for the elbow is readily adaptable. For traction directly on the shoulder joint, as in fractures of the glenoid, the wire is inserted through the humerus in an anterior posterior direction, one inch below the surgical neck Traction on the arm may be instituted by a wire inserted through the olecranon process

THE ELBOW

The most serviceable position for the elbow is slightly less than a right angle to the arm with the forearm in supination or midway between supination and pronation.

Casts

A plaster cast for immobilizing the elbow in the above position should extend from the metacarpophalangeal joints to as high in the axilla as is consistent with the comfort of the patient. The forearm may be held in midposition or supination as desired. The cast may be bivalved and the posterior half used as a splint If necessary hinges may be incorporated at the elbow to permit motion as described for the knee

Splints

Fixation may be maintained by means of a splint on either the anterior or posterior surfaces of the extremity the posterior splint, however is more efficient and more comfortable This apparatus consists of an arm and forearm piece which conforms to the posterior surfaces of the hand, forearm and arm, from the metacarpophalangeal joints to a point on the arm at a level with the posterior axillary fold Since the normal position for the forearm as related to the arm is approximately 15 degrees valgus, the forearm piece on the splint must be joined to the arm piece at a corresponding angle

A right angle elbow splint following the inner aspect of the arm and the volar aspect of the forearm, and terminating at the middle of the palm, is em

ployed more often for lesions of the forearm than of the elbow With this apparatus the forearm is maintained in the midposition between supination and pronation

A simple splint for enforcing supination of the forearm has been described by Funsten This consists of a steel bar which extends along the inner side of the arm and forearm from the axilla to the palm, and is bent at the elbow to 90 degrees. At the palm the longitudinal bars end in an oval band, through which the four fingers are thrust. Another band with a strap is applied just above the wrist joint, to steady the brace and prevent rubbing The arm above the elbow is held securely by two circular bands with straps attached one at the upper extremity of the splint and the other as close to the elbow joint as possible In applying the brace, the distal band is first slipped over the fingers onto the palm The inner bar is then approximated to the arm as the forearm and hand are held in the proper degree of supination. This brace is also useful in pronation contractures and for maintaining the wrist in the hyperextended position.



Fig. 48.—Right angle lateral and posterior splints for elbow and forearm.

The majority of apparatus for either suspension or traction of the upper extremity is extremely cumbersome and considerable time is required for its assembly A light, simple, and efficient splint has been designed for this purpose. This traction apparatus consists of a Murray splint (a Thomas arm splint with a hinge joint at the ring), to which is attached two U-shaped arms, each with a pulley at the top One of these arms is fixed at a right angle to the Murray splint and may be adjusted proximally or distally to correspond to the level of the elbow joint. The second arm is attached to the base of the upright piece by a hinge joint which has a range of motion commensurate with complete extension of the elbow or flexion to 90 degrees; thus, traction is permitted with the elbow in full extension, partial flexion, or at a right angle Both of these arms should be of sufficient length to extend at least six inches beyond the hand. At the distal end of the Murray splint two pulleys are fastened to adjustable transverse bars. An adhesive strip two inches wide is applied to the medial and lateral aspects of the forearm and extended at least three inches beyond the fingers. The loose ends of the strip are attached to a spreader block with a rope through the center For traction with the elbow at a right angle, the forearm is suspended by a rope

which is passed through the pulley on the upright bar and distally to a pulley on the end of the Murray splint. Counter traction against this force is obtained by passing a loop of cloth around one side of the Murray splint proximal to the elbow and across the anterior surface of the arm to the opposite bar. The second U-shaped arm is utilized for traction with the elbow partially flexed. The desired degree of flexion is obtained by traction on a rope from the first to the second bar.

Traction in a line horizontal to the humerus may be secured by a Kirschner wire through the olecranon process, by adhesive strips on the lower third of the arm, or by means of a cuff passed around the flexed forearm close to the elbow. A rope for carrying the weights is then extended distally to the second pulley onto the end of the Murray splint. The distal end of the Murray splint is supported across a small bedside table or on a pedestal made of steel rods.

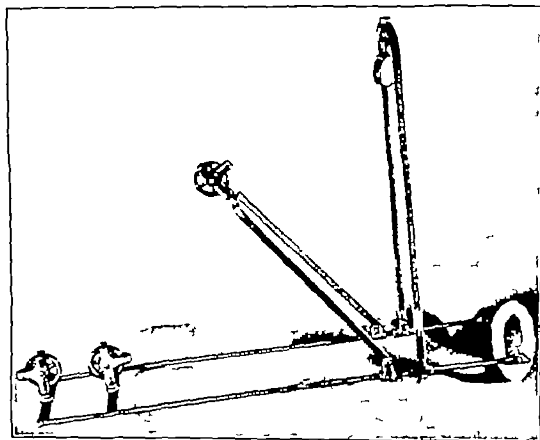


Fig. 49.—Portable splint for suspension or traction of upper extremity. Upright arm for traction with elbow at 90 degrees. Adjustable arm permits traction at any degree of flexion or extension of elbow.

Braces

Braces for the elbow may be made with longitudinal lateral bars of steel connected by metal bands and fastened by straps with buckles as for braces of the lower extremities. The arm and forearm may, if desired, be encased in corsets of leather attached to the braces. Hinges may be applied at the elbow to limit or restrict flexion and extension.

THE WRIST AND FINGERS

Since, in affections of the wrist, there is an ever present tendency toward palmar flexion, the most serviceable position is extension or dorsiflexion.

Casts

Immobilization of the wrist may be effected by a cast from the bases of the metacarpal bones to just proximal to the elbow As a rule, however when complete fixation is desired, the "sugar tong splint is employed for less stable fixation, metal splints are preferable

Splints

The Simpson ' sugar tong ' splint provides an excellent means of im mobilization for the wrist and forearm This apparatus firmly fixes the wrist and prevents pronation and supination of the forearm yet is light and inexpen sive The method of application is as follows

The bony prominences of the elbow are thoroughly padded by circular bandages of outing flannel. The hairs of the forearm are not shaved although the skin is thoroughly cleansed. With a cloth bandage the exact length of the

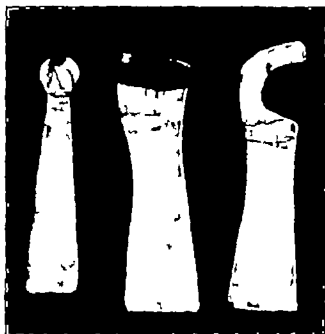


Fig. 40.—Ball peen, cock up, and Colles splint for wrist joint.

proposed splint is measured from just proximal to the heads of the metacarpal bones along the anterior surface of the forearm, around the elbow and down the posterior surface of the forearm to a point just proximal to the heads of the metacarpal bones on the dorsum of the hand A plaster reinforcement of equal length and approximately three inches in width is then spread on a table and carefully smoothed, and a circular space is cut out at one end for the thenar eminence With the forearm in neutral position the reinforcement is first applied to the palm of the hand, thence carried up the forearm anteriorly and around the elbow and down again on the dorsal aspect of the forearm to the heads of the metacarpal bones. The reinforcement is maintained in firm contact with the skin by an ordinary roller bandage. In the event of undue soft tissue reaction, the roller bandage may be split along the radial and ulnar borders, releasing the dorsal portion while the anterior portion is allowed to remain firmly adherent. As the postoperative reaction subsides, the splint is easily tightened by additional turns of the bandage and adhesive tape.

A simple splint made of sheet metal, called the cock up splint, is useful for preventing palmar flexion This splint should extend from the middle of the palm to the upper third of the forearm, and a notch should be cut over the palm for the thumb and thenar eminence. At the wrist joint, the splint is bent backward or cocked up to hold the hand in the desired degree of dorsiflexion or extension.

The ball peen splint is similarly constructed although the distal end should be hemispherical to conform to the palm of the hand

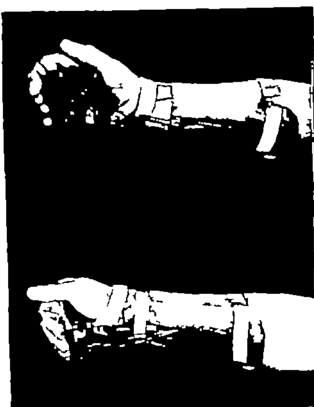


Fig. 51



A



B

Fig 52.

Fig 51 —Bunnell splint. Outrigger with metal roller bent to give desired direction of pull to rubber bands. In upper view the wrist is dorsiflexed, with proximal finger joints in extension. When muscles are relaxed, rubber bands pull wrist into neutral position with flexion of proximal finger joints. (From Bunnell S. J Bone & Joint Surg 28 732, 1946.)

Fig. 52.—*A*, Bunnell knuckle-bender splint, designed to flex and exercise proximal joints of fingers. *B* Leather loop and rubber bands are used to draw thumb into opposition out rigger with tube roller draws fingers into extension and corrects claw hand. (From Bunnell, S. J Bone & Joint Surg 28 732, 1946.)

Simple splints for immobilization of the separate fingers, or for correction of deformities and contractions of one or more fingers, may be made of aluminum tin wood, or of plastics, such as aceto-butyrate cellulose acetate and vinyl chloride. For the construction of such splints a tracing is made of the forearm, hand, and affected fingers on strong wrapping paper, and this pattern is transferred to sheet aluminum or other metal. The splint is then cut to the desired dimensions. If the affected hand is severely contracted, a tracing of the opposite hand may be used. For correction of hand contractures a system of elastic or spring splinting is necessary to change joints from a nonfunctional to a functional position. By this system, the joints are actually mobilized and are thereby able to rid themselves of the factors which cause stiffness. The wrist is forced into dorsiflexion the joints of the fingers into flexion, the thumb into

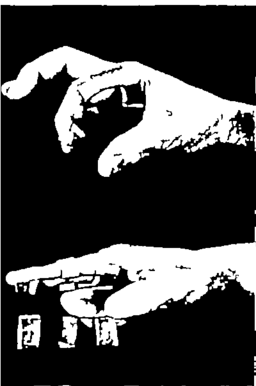


Fig. 53.



Fig. 54.

Fig 53.—Safety-pin splint, used to straighten the finger. The spring wire is 0.033 inch. Two views show flexion and extension mechanism of splint. (From Bunnell, S.: J Bone & Joint Surg 28 732, 1946.)

Fig. 54.—Splint made from clock spring, for extending and exercising the fingers. (From Bunnell, S. J Bone & Joint Surg. 28: 732, 1946.)



Fig. 55.

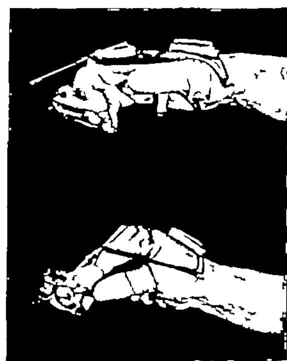


Fig. 56.

Fig. 55.—Suspension splint for radial palsy (Thomas). Splint provides muscle balance and complete freedom of movement. (From Bunnell, S. J Bone & Joint Surg 28: 732, 1946.)

Fig 56.—Knuckle-bender splint used in paralysis of median and ulnar nerves. Upper photograph shows typical claw hand lower photograph shows position corrected by the pull of rubber bands, which straighten the clawed fingers flex th proximal joints of the fingers, draw the thumb into opposition, and curve the metacarpal arch. (From Bunnell S.: J Bone & Joint Surg. 28: 732, 1946.)

opposition, and the curve of the palmar arch is restored Bunnell terms this "Functional Splinting" Under certain circumstances, rigid splinting is necessary, though only that part which requires immobilization should be included in the rigid splint.

Braces

Braces are usually applied to the wrist for the purpose of complete immobilization Joints are practically never affixed Leather corsets, reinforced with steel bars, are the most satisfactory these are constructed over a plaster of Paris model.

APPARATUS FOR INDUCING MOTION

Limited or impaired motion in the ankle knee hip elbow and wrist may be improved or restored by special mobilizing apparatus.

The Ankle

The apparatus for mobilizing the ankle is constructed of a short metal splint with a movable joint The portion of the splint proximal to the ankle consists of two lateral bars connected posteriorly by a padded metal trough. The leg is held in position by anterior straps. Distal to the joint is an upright metal sole plate with straps which pass anteriorly around the foot. Plantar flexion is obtained by weights attached to the heel of the sole plate Dorsiflexion is carried out by means of a rope fastened to the top of the sole plate, thence passed through a pulley on an upright bar at the proximal end of the splint, to the patient's hands. The patient may then accurately regulate the range of motion of the ankle with the rope. This apparatus may be mounted on a metal pedestal or fixed to a small table or stool by means of a carpenter's clamp

The Knee

Every apparatus described herein for restoring motion to the knee joint has the following feature in common With the thigh fixed at the desired angle, the knee is flexed and extended by means of a system of ropes and pulleys extending from the distal portion of the apparatus to an overhead pulley thence to the patient's hand thus, motion is at all times under the control of the patient. If the patient is confined to bed, the apparatus is suspended from a Balkan frame.

A simple form of apparatus for mobilizing the knee embodies the use of cuffs on the thigh and leg A large cuff is fastened to the thigh just proximal to the knee and suspended from an overhead frame by means of an adjustable strap A second cuff is fastened around the leg just proximal to the ankle. A rope is attached to this cuff and passed through a series of pulleys to the head of the bed. By adjustment of the strap and rope the patient may carry out passive motion of the knee to any desired degree.

A slightly more complicated type of apparatus is employed following arthroplasties when immobilization of the knee against lateral motion is desired This device is constructed upon a simple Thomas splint four inches longer than the affected extremity A well padded metal trough which conforms to the posterior surface of the thigh is attached to the lateral bars, and the thigh is firmly bound to the splint by means of straps with buckles. Just distal to the knee is a

movable inner splint with a foot plate, which is attached to the Thomas splint with a hinge joint. This inner splint may be adjusted proximally and distally on the Thomas splint, to permit the hinge to conform to the level of the knee joint. The posterior portion of the inner splint also has a metal trough which conforms to the posterior surface of the leg and to which anterior straps with buckles are attached encasing the leg firmly and thus providing thorough immobilization The plate on the inner splint maintains the foot at a right angle to the leg For exercises, the distal end of the Thomas splint is suspended from an overhead frame at the proper elevation for the desired range of motion. A rope is tied to the distal end of the inner splint and passed through a system of pulleys on the overhead frame to the head of the bed by this means, the Thomas splint remains stationary during exercises, while the inner splint moves up and down with flexion and extension of the knee, being controlled by the rope in the patient's hands.

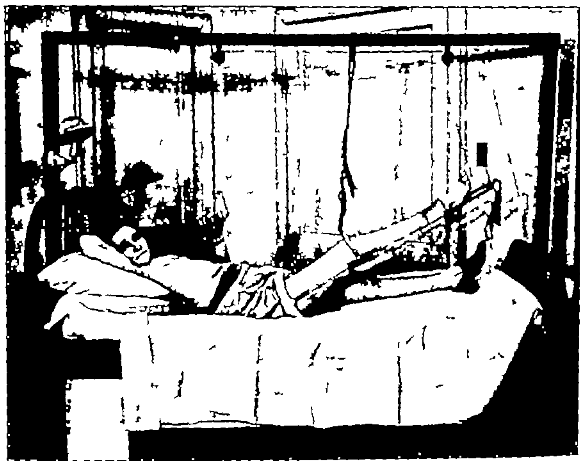


Fig. 57—System of pulleys and ropes for increasing range of motion in knee. Extremity immobilized in hinged Thomas splint.

When the patient is no longer bedridden the principles of the above apparatus may be incorporated in one which is portable. This appliance consists of a Thomas splint with a foot plate for supporting the ankle at a right angle to the leg The splint is hinged at the knee, straps and buckles are applied for firm immobilization of the thigh and leg and the portion encircling the thigh is mounted upon a pedestal the height of a chair Weights are attached to the foot of the splint and a rope is carried from the foot piece through a system of

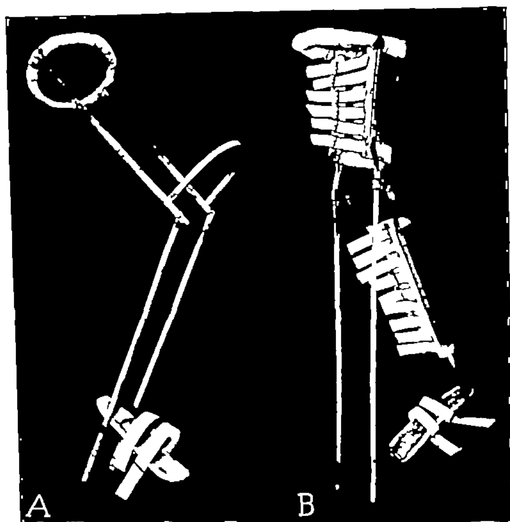


Fig. 51.—*A*, Hinged Thomas splint. Adjustable foot plate maintains foot and ankle in optimum position. *B*, Arthroplasty exercise splint. Movable portion of splint may be adjusted for extremities of different lengths.

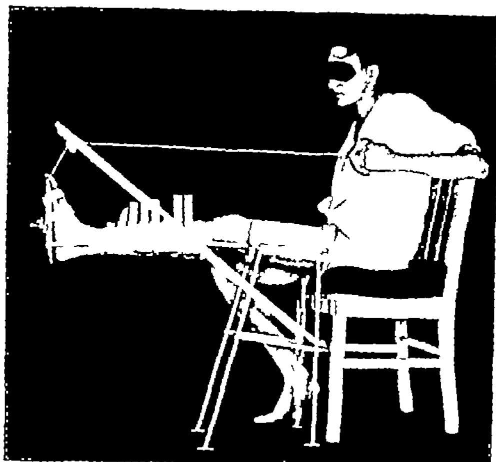


Fig. 59.—Portable apparatus for mobilization of knee.

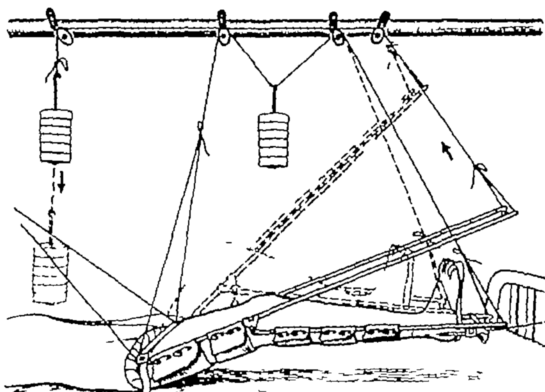


Fig. 60.—Thomas splint with Pearson attachment, rigged for knee and hip exercises.

pulleys fastened to an upright bar to the patient's hand The weights induce flexion of the knee by gravity and the patient extends the joint by traction on the rope.

The Hip

A simple form of mobilization, described for the knee, is also applicable to the hip A cuff is fastened around the ankle and a rope passed from this cuff through a series of pulleys to the bed. As the patient pulls on the rope, the hip is flexed while the knee remains extended If the extended position of the knee is unduly strained from the exercises the leg may be immobilized in a Thomas splint and the rope fastened to the end of the splint.

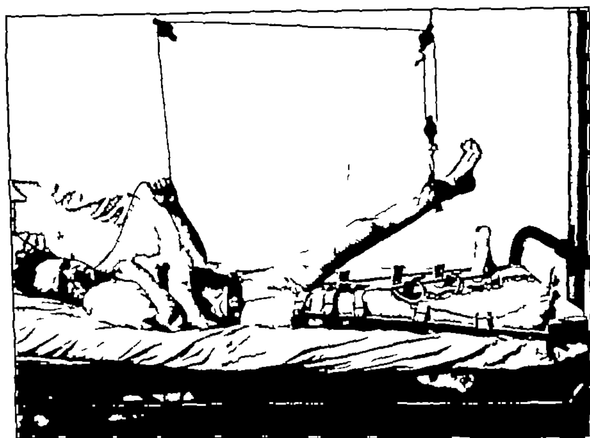


Fig. 61 —Passive motion of hip controlled by patient, the end of the rope being attached to cuff about ankle.

A device similar to the Thomas splint is constructed with a joint at the hip which allows a free range of motion The trunk and limbs are held securely by straps and buckles. A weight may be fastened to the foot of the splint, or the weight of the limb alone may be sufficient to produce extension and hyperextension of the joint. Flexion is accomplished by pulling on a rope which passes through two pulleys on an overhead frame and is attached to a cuff around the ankle. The extremity may be so suspended that active abduction and adduction are possible.

Portable apparatus for the hip other than that employed for small children is somewhat cumbersome and therefore not practicable.

The Arkin Movable Traction Carrier is a simple overhead frame which carries the traction. Instead of being fixed to the bed, this frame is suspended from another frame attached to the bed by a joint, the latter being so constructed

as to permit motion in flexion, abduction, and adduction. The joint is placed directly above the involved hip allowing the limb to remain parallel with the frame in carrying out the motions. A handle is attached to enable the patient



Fig. 62.—Roller-skate exerciser useful for securing abduction and adduction of hip

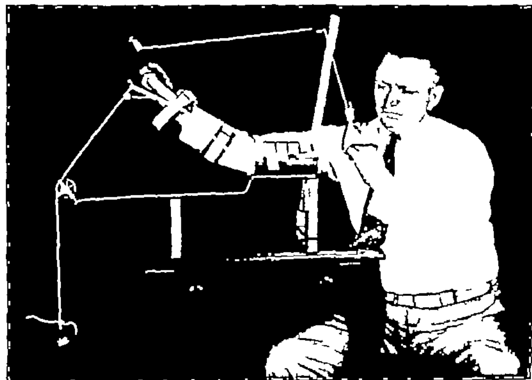


Fig. 63.—Apparatus for increasing motion in elbow joint.

to put his legs through the desired range of passive motion. The apparatus is counterweighted to balance the weight of the leg active motion is then possible with little effort on the part of the patient and without the use of the handle.

Roller skates on a double incline plane platform are useful for securing abduction and adduction The angle of the plane may be regulated according to the requirements of the patient.

The Elbow

The apparatus for mobilization of the elbow consists of two lateral bars extending from just below the level of the axilla to the palm, with a joint at the elbow The distal ends of the bars are connected by an oval shaped band of metal. Posteriorly the lateral bars are connected by semicircular metal bands with corresponding straps. An upright metal bar provides support for a pulley This apparatus is clamped to a small table or stool. Weights are placed on the distal end of the splint to produce extension of the elbow and flexion is secured by pulling on a rope which extends from the distal end of the splint through the pulley to the patient s hand

References

Arkin A. M.: Movable Traction Carrier An Apparatus for Combining Traction With Motion at the Hip, J Bone & Joint Surg 21 1032, 1939

Bennett George E., Cobey Milton C., and Kendall H O: Molded Plaster Shells for the Rest and Protection Treatment of Infantile Paralysis J A. M A. 109 1120 1937

Bernstein A., and Stone, J R. March Fracture A Report of 307 Cases, and a New Method of Treatment, J Bone & Joint Surg 26 743 1944

Böhler Lorenz Treatment of Fractures (Translated by M E. Steinberg), Vienna, 1929 Wilhelm Maudrich, pp 87 127 155.

Bunnell, S.: Active Splinting of the Hand, J Bone & Joint Surg 28 732 1946.

Caldwell, J A.: Treatment of Fractures in the Cincinnati General Hospital Ann. Surg 97 161 1933

Caldwell J A. Treatment of Fractures of the Shaft of the Humerus by Hanging Cast Surg. Gynec. & Obst. 70 421 1940

Campbell, Willis C., and Mitchner J M.: An Apparatus for the Correction of Flexion Contracture of the Knee J Bone & Joint Surg 8 416 1926.

Carrell, W B: Fixation Frame for Pott s Disease in Young Children J Bone & Joint Surg 9: 24, 1927

Crutchfield, W G: Skeletal Traction for Dislocation of the Cervical Spine. Report of a Case, South. Surgeon 2 156, 1933.

Dickson, F D., and Diveley Rex L. Functional Disorders of the Foot, Philadelphia, 1939 J B. Lippincott Co.

Funsten, Robert V Suggestions From the Brace Shop J Orthop Surg. 2 345 1920

Geckeler Edwin O: Plaster of Paris Technic, Baltimore, 1944 The Williams and Wilkins Co

Griswold R. A., Goldberg, H., and Joplin, R.: Fractures of the Humerus Am. J Surg 43 31 1939

Hart, V L. Corrective Cast for Flexion Contracture Deformity of the Knee, J Bone & Joint Surg 16 970 1934.

Hawley G W Fracture and Orthopedic Table, J A. M. A. 60 1850 1913

Jordan, Henry H: Orthopedic Appliances Oxford Univ Press, London, 1930

Kulowski, J Flexion Contracture of the Knee, The Mechanics of the Muscular Contracture and the Turnbuckle Cast Method of Treatment, With a Review of 55 Cases, J Bone & Joint Surg 14 618 1932.

La Ferte, A. D., and Nutter P D: Treatment of Fractures of Humerus by Means of Hanging Plaster Case— Hanging Cast Ann. Surg 114 919 1941.

La Ferte, A. D., and Rosenbaum, M. G The ' Hanging Cast in the Treatment of Fractures of the Humerus Surg., Gynec. Obst. 65 231, 1937

Lewin, Philip: The Foot and Ankle Their Injuries Diseases, Deformities and Disabilities, Philadelphia, 1940 Lea and Febiger

Luck, J V Plaster of Paris Casts. Experimental and Clinical Analysis J A. M. A. 124 23 1944

Roberts, P W: Prevention and Treatment of Weakfoot in Children, J A. M A. 75 237, 1920.

Stryker H. Walking Cast (Personal communication.)

Stryker, H A Device for Turning the Frame Patient, J A. M. A. 113 1731, 1939

Taylor Charles Fayette: The Spinal Assistant Tr Am. Orthop. A. 12 15, 1899

Thornton, Lawson Fractures of Humeru Treated by Means of the Hoke Plaster Traction Apparatu J Bone & Joint Surg 12 911 1930

Trueta J The Principles and Practice of War Surgery With Reference to the Biological Method of the Treatment of War Wounds and Fractures, St. Louis, 1943, C. V Mosby Co.

CHAPTER III

SURGICAL TECHNIC

The requirements of surgical technic begin with the examination and preoperative care of the patient. Careful attention to the details elaborated in Chapter I is of immeasurable benefit in the proper execution of the surgery and the prevention of postoperative complications. Confident that the preoperative preparation has been carefully and thoroughly carried out, the anesthetist is capable and reliable, and that the operating room personnel has all the necessary equipment properly prepared and available, the surgeon can devote his undivided attention to the actual operative procedure. The present chapter deals with the management of orthopedic operating rooms, surgical equipment, and aseptic surgical technic To avert repetition in subsequent chapters, a few technics common to many procedures, such as tendon suture fixation of tendons to bone, internal fixation of bones and bone grafting are described in this chapter

OPERATING ROOMS

We realize that ideal conditions as to arrangement and equipment of operating rooms are not possible in every general hospital. In institutions where surgery is limited to orthopedic affections, however one has every reason to expect perfect operative surroundings.

In the Campbell Clinic, the department in which operations are performed on clean cases consists of an anteroom, sterilizing and supply room, doctors dressing room, a small room for developing roentgenograms, a room containing air-conditioning equipment, and two operating rooms. These are in an isolated section of the building Two sides of the operating rooms are constructed of hollow semitranslucent glass bricks which afford a maximum of light and insulation. There are no open windows in the operating rooms, and the only air which comes into these two rooms enters through the doors. In an endeavor to limit the number of objects which will catch dirt and dust, all cabinets, radiographic view boxes, and overhead lights are recessed into the wall. For the same reason only the absolutely essential operating equipment is kept in the operating rooms proper All other equipment, as solution basins and clothes hampers, is kept in a separate room The operating rooms are thoroughly cleansed every day with Lysol solution.

Between the two operating rooms is the air-conditioning equipment. Unquestionably air-conditioning has several advantages By regulation of the temperature of the operating rooms to 80 degrees during the summer both surgeons and patients are prevented from becoming dehydrated. Further the possibility of infection from perspiration soaked gowns, or from perspiration which might fall into the wound, is reduced to a minimum. Hart has shown conclusively that many infections are the result of contamination from organisms in the air With this in mind colony counts of exposed blood plates are made routinely The number of colonies is directly proportionate to the operating

room traffic. The air-conditioning machine is also advantageous in that it maintains a positive pressure with a constant flow of filtered air through and away from the operating room, thus minimizing the danger of air contamination

To prevent the circulation of glove powder through the operating rooms, excess powder is discarded adjacent to the intake conduit of the air-conditioning apparatus and is immediately whisked out of the room into the filtering apparatus.

In all infected cases, we operate on another floor of the building in an entirely separate and complete operating suite

SURGICAL EQUIPMENT

No attempt will be made to describe in detail all the surgical equipment essential to the proper execution of orthopedic operations. Good equipment is, of course, one of the first requisites of good surgery Every orthopedic surgeon appreciates this fact when he attempts to operate in general hospitals where the orthopedic armamentarium is limited to a few outmoded chisels, time worn wooden mallets, and various ancient instruments which have long outlived their usefulness.

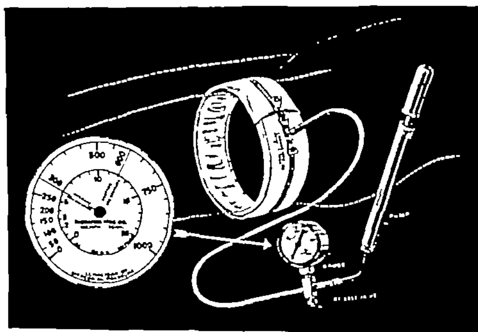


Fig 64.—Campbell Boyd pneumatic tourniquet. (Courtesy of Richards Manufacturing Co. Memphis, Tenn.)

Operating Tables.—A fracture table frequently serves a double purpose, being utilized also as an operating table Thus, transference of the patient from the operating table to the fracture table for the application of a cast following operation is unnecessary

Tourniquets.—In operations upon the extremities, the procedure is materially facilitated by the use of a tourniquet. Under no circumstances, however should a tourniquet remain in situ longer than an hour and a half and preferably not more than an hour

The tourniquets in common use not infrequently cause serious damage to the nerves and blood vessels and lead to persistent neuritis or tourniquet

paralysis. This is particularly likely in the upper extremity To preclude such eventualities a pneumatic tourniquet should be employed if at all possible thus, pressure may be evenly and consistently applied over a large area

The amount of pressure to be applied depends upon the size of the individual extremity For an adult of average size, twelve pounds of pressure for the thigh and 250 to 300 mm of mercury for the upper extremity are the maximum The pressure for children is proportionately lower In the upper extremity greater care must be exercised than in the lower

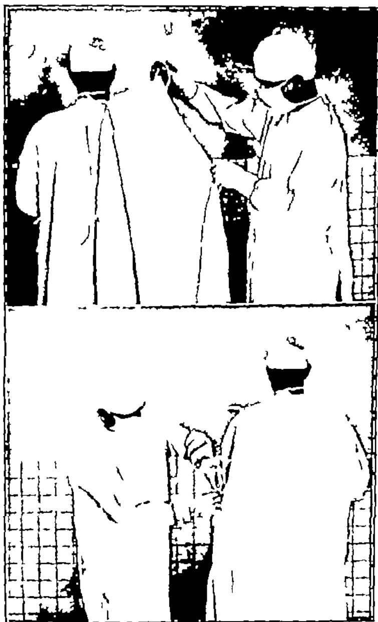


Fig. 65 —Double-flap gown, designed by Dr C. N Carraway back as well as front of gown remains sterile.

Prior to the application of a tourniquet, the venous blood is expressed from the limb the extremity is elevated for two minutes, then bound tightly around with a clean cotton elastic bandage over the preparatory dressings, beginning at the fingers or toes and proceeding proximally to the level at which the

tourniquet is to be applied. The cotton elastic bandage is more durable than the Esmarch rubber bandage and may be sterilized once or twice before losing resilience. For operations on the proximal part of the upper extremity, a pneumatic tourniquet may be impracticable; in this event, a second cotton elastic *bandage is applied evenly and smoothly around the shoulder at the level of the* axilla. Below the shoulder joint an ordinary blood pressure apparatus is satisfactory for the upper extremity. The Campbell Boyd pneumatic tourniquet or the one devised by Conn are excellent for the lower extremity.

Gowns.—The gown of the surgeon should be made with a double flap down the entire back. We are indebted to Dr. C. N. Carraway, of Birmingham, Alabama, for supplying a pattern from which these gowns are made. The circulating nurse should tie the inner flap and a sterile nurse the outer flap. Undoubtedly, there is a *possibility of contamination when the gown* is open and the back is tied by an unsterile circulating nurse, as the back of the surgeon often comes in contact with sterile instrument stands and with the gowns of sterile nurses and assistants.



Fig. 66.—Mask devised by Dr. John Staige Davis closely conforms to shape of nose and face. Insert shows malleable aluminum strip incorporated in upper seam.

Sponges.—Two types of sponges are commonly employed in orthopedic operations: the ordinary square sponge in two sizes, three by three and four by four inches, and long gauze strips. The latter are made in several sizes, the smallest being one and one half by eight inches, and the largest three by thirty-six inches. If the wound is deep and in an hemorrhagic area, only the long sponges should be used. Sponges absorb blood and become the color of the wound and a square *sponge may easily be left in the* wound unnoticed, causing a medico-legal catastrophe. For this reason square sponges should never be used for packing off hemorrhage; we do not employ them even for sponging in large wounds. Small strip sponges serve both purposes equally well. One

end of the sponge may be left protruding from the wound with a hemostat attached thus avoiding the possibility of *being overlooked* when the wound is closed.

Towels.—The towels ordinarily employed for abdominal surgery are too small for surgery of the extremities. Towels should be of sufficient length and width to cover the distal end of either the lower or upper extremity and overlap several inches. Large towels facilitate draping and reduce the danger of contamination of the surgeon

Gloves.—Routine surgical gloves are employed in the majority of orthopedic operations. In the presence of gas gangrene or pyogenic infections, such as osteomyelitis, however the sense of touch is of little value as the technic *usually is rather gross* heavy duty seamless industrial rubber gloves are therefore more suitable in that they afford added protection.

Masks.—In an endeavor to reduce the possibility of contamination of the wound from organisms in the air we employ a mask devised by Dr John Staige Davis, which closely conforms to the shape of the nose. A thin, malleable aluminum strip which may easily be bent over the nose and face and serves to hold the mask in place, is incorporated in the upper seam. This feature is particularly advantageous during the season when colds are prevalent. Numerous cases have been reported wherein the organism which caused an operative infection was similar to that isolated from the upper *respiratory tract of some member of the operating room personnel.*

Surgical Instruments

An ample supply of special instruments, all in good working order is absolutely essential In our experience the finest surgical instruments obtainable are the most economical

Scalpels.—A wide variety of sizes and shapes of scalpels should be available to meet the demands of any case. Operating knives with removable razor like blades are suitable only for skin or soft tissue incisions. Knives are frequently used not only for cutting purposes, but for prying inelastic soft structures from the bone and dissection at the junction of soft tissues and bones causes thin blades to break. For this reason ordinary scalpels are preferable. The scalpels should be sharpened after each operation.

Hemostats.—Small and delicate instruments such as the Halstead and Kelly clamps should be reserved for inducing hemostasis. Clamps which are utilized for manipulating bones or exerting tension on nonresilient or non elastic soft structures must, of course, be of heavier construction.

Chisels and Osteotomes—These instruments are similar to those employed by a woodworker but usually are made entirely of metal, preferably rustless steel. Nickel or chrome-plated instruments rapidly chip and small fragments of plating *may be overlooked and left in the wound, to be demonstrated* in postoperative roentgenograms to the embarrassment of the surgeon The chisel has one cutting edge, whereas the osteotome has two sides which taper equally to a cutting edge The cutting edges vary in width from three-sixteenths inch to two inches.

Gouges.—A gouge differs from a chisel in that its cutting surface is curved from side to side and frequently also from before backward. Since the sizes

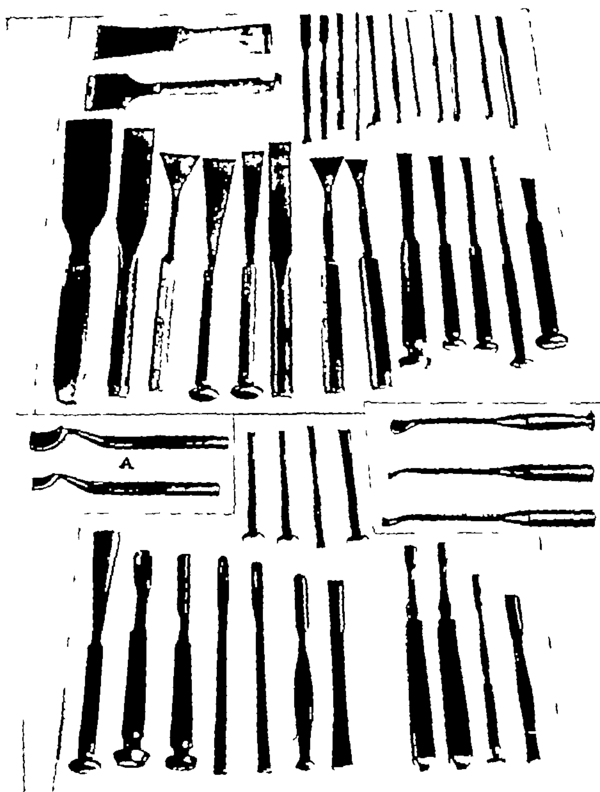


Fig [illegible].—Chisels, osteotomes and gouges. A Smith Petersen gooseneck chisels used in mold arthroplasty of hip

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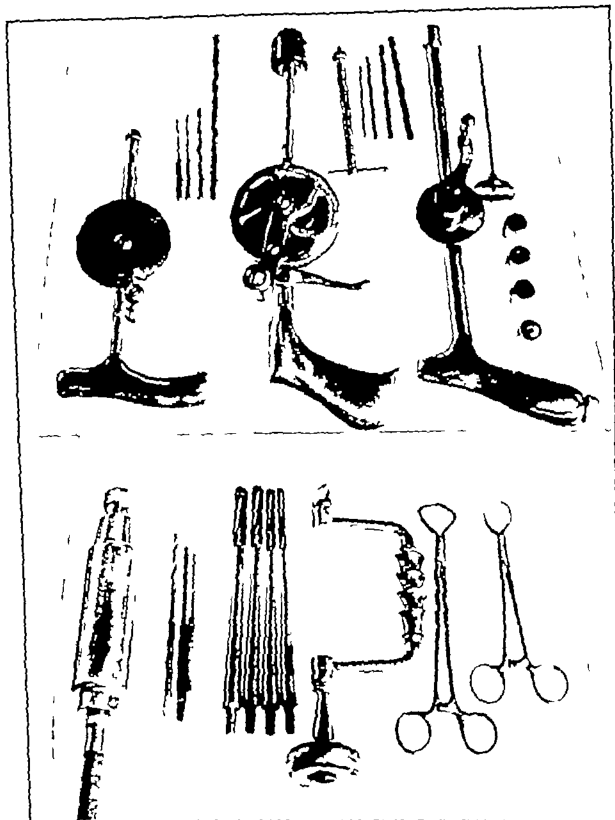
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A



B

Fig. 69.—A Drill holders Stille, Chick, and Richards-Lovejoy B Electric drill, Murphy reamer drills, and Lewis clamp.

and shapes of gouges vary they may be used for cutting grooves of different depths or for curving flat surfaces.

Mallets.—All mallets should be constructed of metal as this material is most durable and most easily sterilized. For heavy duty the Meyerding mallet which resembles a potato masher in shape, is preferable Lighter mallets are suitable for use on the small bones, such as those of the fingers and wrist. Mallets with a lead filled head quickly lose shape and wooden mallets are too light and split or crack after being sterilized a few times.

Drills and Drill Holders—Drill points usually employed vary in size from No 16 to No 32 The larger drills, or reamers, cut holes in sizes from 5 mm. to 8 mm Those designed by Murphy or Henderson are particularly efficient. When a semicircular hole is desired for passing a suture through bone, the Lewin clamp which is similar to a towel clip with heavy jaws, is most appropriate.

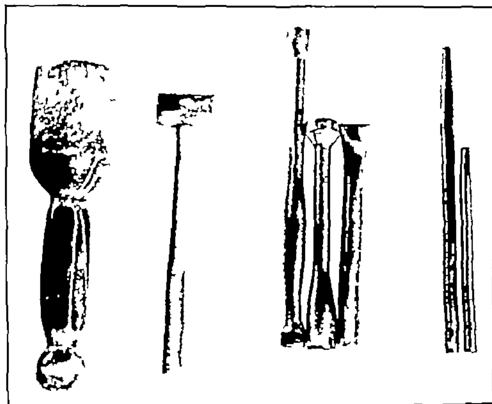
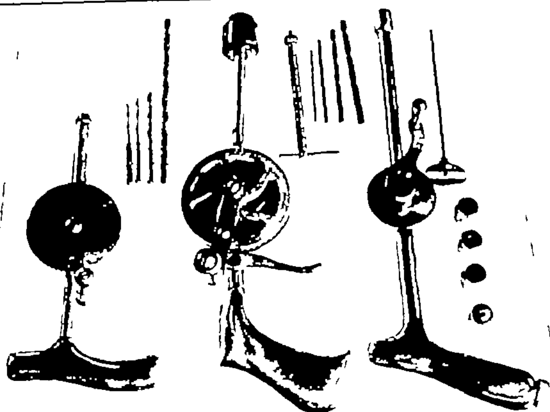


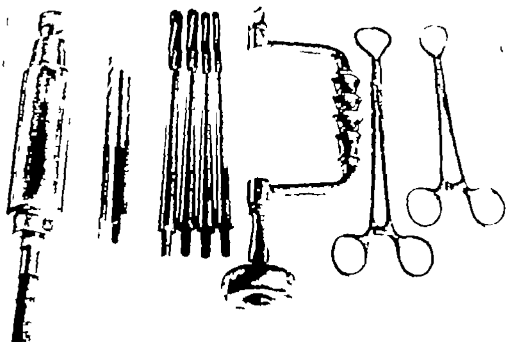
Fig 63.—Meyerding mallet, small metal mallet, special drivers with tunnel in center Freiberg impact r and inlays.

The most satisfactory type of drill holder is that made with a wheel and gear of high ratio this assures smooth action and diminishes the risk of breaking the drill point flush with the bone by side-to-side motion.

Instruments to Smooth Rough Bony Surfaces.—These instruments are generally employed in arthroplasties. Those designed by Putti and others consist of round, flat, broad, and narrow rasps and files with broad or tapering points A special device composed of a male and a female instrument, has been invented by Murphy to reproduce the ball and socket of the hip The female instrument is a cup shaped metal rasp two inches in diameter which conforms to the shape of the normal head of the femur On rotation, the rasp-like edges inside the cup make the surfaces smooth and round. The male in

A





B

Fig 69 —A Drill holders Stille, Chick, and Richards-Lovejoy B Electric drill, Murphy reamer drills, and Lewin clamp.

strument, a hemispherical burr two and one fourth inches in diameter is utilized to smooth the reconstructed surfaces of the acetabulum

For the mold arthroplasty of the hip special instruments designed by Smith Petersen to shape the femur and acetabulum accurately are mandatory

Bone-Cutting Forceps and Rongeurs.—Bone-cutting forceps are constructed on the same principles as wire cutters. Compact bone of large circumference is more easily cut with double action forceps, while single action bone cutting forceps are used for smaller and less dense bone. Rongeurs, which are similar in action to bone-cutting forceps with jaws resembling those of curettes, are utilized to cut out small sections of bone the size of the jaws. These also are obtainable with double or single action

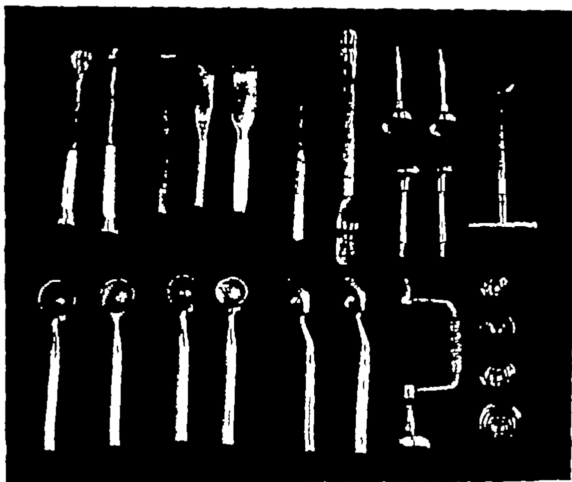


Fig. 70—Instruments for mold arthroplasty instruments to smooth rough surfaces. Those in the lower row were designed by Smith-Petersen. Smith-Petersen chisels are illustrated in Fig. 67

Bone-Holding Instruments.—Instruments used primarily to manipulate bony fragments must be of heavy construction, with jaws of sufficient width to conform to the diameter of the bone. Large Ochsner forceps are suitable for holding the smaller bones, and the larger Lane bone-holding forceps for bones such as the femur and humerus. Rush has devised a particularly effective instrument which is especially adaptable to the onlay bone graft operation.

Electric Saws and Drills.—As is true of other surgical equipment, the simplest electrical apparatus is the most satisfactory The Luck, Albee, and

Fig. 71.—Single and double action rongeurs and bone-cutting forceps.

Fig. 72.—Bone-holding instruments of Rush, Lane, and Albee and Ochsner clamp.

Fig 73.—The Luck saw (Courtesy of Zimmer Manufacturing Co, Warsaw Ind.)

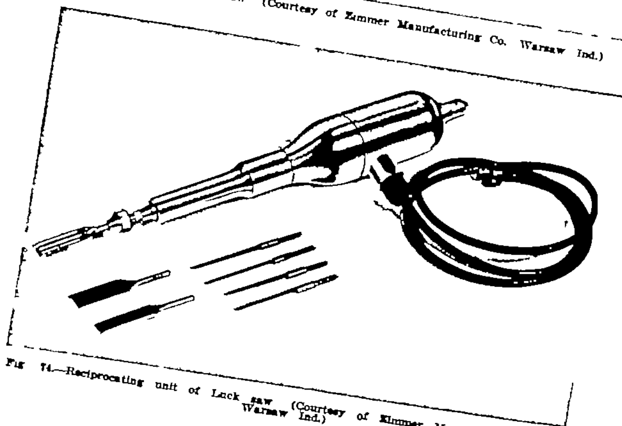


Fig 74.—Reciprocating unit of Luck saw (Courtesy of Zimmer Manufacturing Co., Warsaw Ind.)

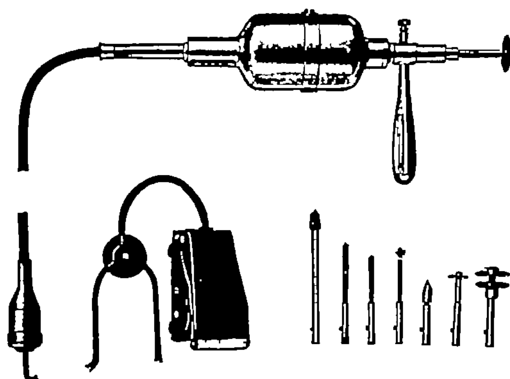


Fig. 75.—Albee electric saw (Courtesy of Kny Scheerer Corp.)

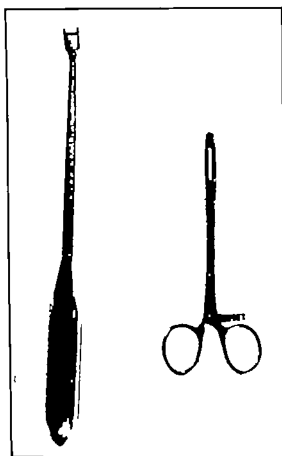


Fig. 76.—Lowe and Breck cartilage knife and Martin clamp.

Fig. 77.—Instruments for skeletal traction.

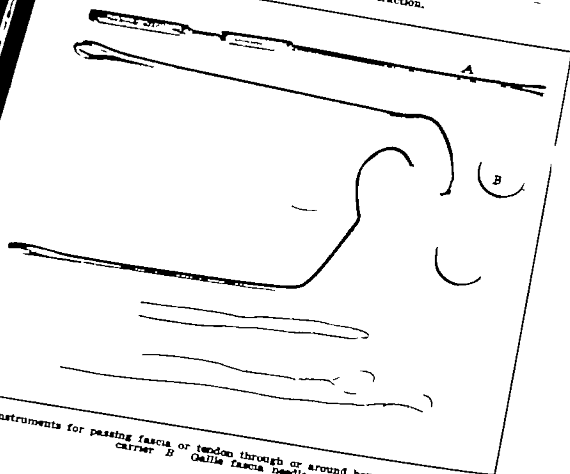


Fig. 78.—Instruments for passing fascia or tendon through or around bone. A, Macey tendon carrier. B, Gallie fascia needle.

Cayo units are efficient For general use, the Luck saw is an excellent instrument The motor, gears, and bearings are sealed and enclosed in a Duraluminum case This unit, together with a segment of electric cord, may be autoclaved, thereby minimizing the danger of contamination The motor is equipped with an ordinary Jacob s chuck thereby permitting the use of an unlimited number of appliances. The saw is capable of rotating twin saw blades at a maximum speed of 2,200 rotations per minute Since the number of revolutions per minute may be regulated with a rheostat, it is well adapted to drilling Cutting burrs may also be inserted for making irregular and curved cuts in the bone and a reciprocating saw attachment is useful in osteotomy Both the Luck saw and the Albee saw are high speed, direct drive units.

The motor of the Albee saw is encased in a sterile metal shell and is connected directly with the chuck. The electric cable passes from an opening in the rear of the shell to a foot switch The cable may be sterilized. The high speed of the saw permits rapid cutting but possibly generates more heat, with consequent damage to the bone, than slower units. The complete unit, including the motor is held in the hands this is not necessarily a disadvantage as the weight is only four pounds.

The Cayo saw presents a new feature in bone-cutting instruments, enabling one to cut sharply curved grafts. An automatic chisel increases its adaptability These instruments work from a reciprocator driven indirectly through a flexible shaft.

Special Instruments.—Instruments for special operations are illustrated in Figs. 76 77 78, 79 106 317 325 335 763 and 1021

Ligatures and Suture Materials

The materials used in the closure of wounds should be chosen according to the nature of the tissues to be sutured All sutures should be inserted with cutting ' needles. When the tissues are under tension, the deep structures are closed with a continuous stitch of No 0 chromic catgut and the subcutaneous structures with plain No 00 or 000 catgut depending upon the depth of the fat. The skin is united with interrupted stitches of medium or fine silk. Running lock stitches of the skin are not satisfactory when considerable tension from postoperative swelling is anticipated, since swelling tightens the stitches and causes ischemia and pressure necrosis of the skin the wound then spreads and the ultimate appearance is unsightly When continuous immobilization is desirable we do not hesitate to leave the skin sutures in place beneath a cast for six to eight weeks

For surgery of the soft tissues, such as tendons stainless steel wire or fine, medium, or coarse braided or plain silk sutures are employed. When feasible stainless steel sutures are preferable for tendon work, in that they are relatively inert and often may be removed with a minimum of surgery after the tendon has healed (Fig 96) The stainless wire varies in size from No 34 for the flexor tendons in the hand to No 28 or No 29 for the tendo achilles

Material for Internal Fixation of Bones

Internal fixation of two osseous surfaces may be accomplished by a variety of apparatus and materials. The technics of internal fixation are described

on pp 115 364 The most popular materials are catgut silk, bone, and metallic appliances of 18-8 S Mo stainless steel or Vitallium.

Chromic catgut and silk have only a limited application they may be sufficiently strong when only slight tension on the sutures is anticipated as in the fixation of tarsal bones.

When osteogenesis and stability are required of the same fixation agent, an autogenous cortical graft and cancellous bone from the tibia, as in the onlay bone graft procedure provide most innocuous and efficient material.

If the use of autogenous bone is impracticable homogenous bone may suffice. *Homogenous grafts or pegs afford a convenient form of fixation*, particularly since the development of the bone bank (p 123) Assuming that the cellular elements of an autogenous graft die, and that the graft merely provides a framework and scaffold for new bone, theoretically homogenous and autogenous grafts should be equally efficient so far as their osteogenic properties are concerned Much is yet to be learned in this regard.

Being brittle and easily broken, chemically preserved homogenous bone has heretofore had a limited field of usefulness. Further replacement of the graft by viable bone proceeded slowly and sometimes incompletely as compared with autogenous bone. Apparently chemical preparation and preservation of the grafts (Method of Orrell the fat is extracted by acetone, the connective tissue by warm potassium hydroxide, and the protein by salt solution) removes or alters adversely a desirable element in homogenous grafts The bone bank may provide a satisfactory answer to the objections to the use of homogenous grafts, syngenesioplastic grafts and chemically preserved homogenous bone

Following the introduction of Lane plates metallic fixation became a subject of widespread discussion Because of several undesirable features, i.e. loosening of the screws with loss of fixation infection, collection of fluid about the metal and, often delayed or nonunion, fixation by metal plates, with few exceptions, was not generally accepted This undoubtedly contributed to the widespread use of autogenous materials. Venable, Stuck and Beach, in 1937 proved that, *except for infection all unfavorable reactions about metals in bone were due to electrolysis* In the course of their experiments with metals, they found that Vitallium an alloy of cobalt 65 per cent, chromium 30 per cent, and molybdenum 5 per cent was completely inert in body fluids and caused no electrolytic reaction Their experience with this metal was so satisfactory that they proposed its use in surgery Clinical experience during the past ten years has established their claims that Vitallium provides the maximum of safety in internal fixation of bone The other alloy recommended for internal fixation of fractures is 18-8 S Mo stainless steel (Type 316) ' This alloy is not entirely inert, as analysis of the surrounding tissues reveals some slight disintegration of the metal for practical purposes, however it is satisfactory

For the complete story of the development of metals in fracture fixation, the reader is referred to a recent book by Venable and Stuck. We feel that their studies represent an epoch in the fixation of bones by metallic appliances and are probably the most important contribution to orthopedic surgery during the past ten years.

Since the advent of the studies by Venable and Stuck, many types of metallic fixations have become both practicable and feasible for example, the

use of screws plates, pins, and wire sutures. The screws should be of the self tapering variety with from 20 to 32 threads to the inch The style of the plate makes little difference, provided it is long enough and strong enough to provide stability and fixation to a fracture of a degree which is equal to the demand in the individual case We have had no experience with the slotted plates (Eggers, or Townsend Gilfillan) which allow telescoping of the fragments and constant contact of the fracture surfaces (Fig 271) In principle, they seem worth while



Fig 79—Smith-Petersen nail Knowles' pin, Neufeld nail, Jewett nail, and Blount Moore blade plate.

In general the use of fixation apparatus which has the widest application is desirable A large number of expensive gadgets with a limited scope of application is unnecessary The majority of requirements may be met by the following stock (1) stainless steel wire sizes varying from Nos 30 32, 34 and 35 (Babcock wire) to Nos 19 20 and 22 (Krupp wire) (2) Kirschner wires (0 093) and pins (0 125) These may be cut into the desired lengths for use as nails or may be employed for skeletal traction Smith Petersen guide pins, or intramedullary pins for the forearm or smaller bones (3) a variety of standard plates and screws (4) Knowles pins in lengths from 2½ to 4½ inches The Knowles pin has a wide application, it may be used as a long screw threaded pin or in lieu of a Webb stove bolt, for fractures of the tibial or femoral condyles, or the neck of the femur (5) an adequate number of special nails or plates, such as the Smith Petersen nail the Neufeld or Jewett nail and the Blount or Moore blade plate By varying the angle a blade plate may be employed for fractures between the base of the neck and the region of the lesser

trochanter of the femur for high or low osteotomies of the femur (Fig 488), or for supracondylar fractures of the femur (Fig 298)

We wish to point out again that only two metals should be used, 18-8 S Mo stainless steel or Vitallium and even these relatively inert substances should not be used in combination

ROENTGENOGRAMS IN THE OPERATING ROOM

Roentgenograms are often necessary during an orthopedic operation. The technicians, therefore, must have some conception of aseptic surgical technic to avoid contamination of the drapes. The portable x ray unit should be carefully washed before being brought into the operating room The technicians are capped masked, and gowned. In many cases, a cassette holder covered with a Lysholm grid is inserted beneath the patient prior to draping in order that the cassette may be properly placed and removed without disturbing the drapes of the patient. The Lysholm grid, used principally for roentgenograms of the hip reduces secondary radiation sufficiently to produce a picture with excellent contrast and detail



Fig 80.—Method of taking anteroposterior roentgenograms of hip without disturbing position of patient or drapes cassette in pan holder is inserted from opposite side. Insert shows plate in place.

Before the tube is placed in position the wound is closed temporarily with towel clips and covered with a sterile towel to obviate the possibility of contamination by dust particles For roentgenograms of the extremities distal to the shoulder or hip joint, the cassette is placed in a sterile pillow case and this in turn is covered by a sterile towel thus insuring at least two layers of sterile drapes on the cassette

Fig. 81.—Lateral view of hip is made with a curved cassette between legs sandbag obviates unnecessary roentgen-ray exposure of assistant.

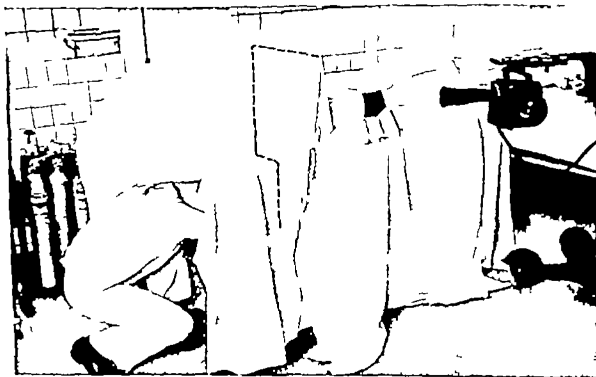


Fig. 82.—Dotted line shows outline of metal bar under drape technician has easy access to curved cassette without disturbing sterile field Towel clips are so placed as not to be superimposed on film.

Usually, the demonstration of bone detail is unnecessary in operating room films, the determination of alignment or position is sufficient. In order to save time, the films are frequently overshot and underdeveloped, or developed in warm solutions. By a new rapid developer a film exposed by the usual technic may be completed within three minutes at a temperature of 65 degrees F This time may be decreased to approximately one and one-half minutes if the fluid is kept at 72 to 74 degrees, and further decreased by overexposure. The films *are left in the hypo only long enough to prevent fogging on exposure to light.* Considerable time is saved by having a small developing room adjacent to the operating rooms.

VISITORS

Visitors should change from street clothes to operating room clothing and should be properly capped, masked and gowned. Those who are not familiar with operating room technic should be informed of the possibility of contaminating sterile drapes and kept at a distance from the operative field. Even visitors who are familiar with the routine of the operating room frequently become so interested in the procedure that they unconsciously contaminate the surgeon or his assistants. For this reason, one person, usually the circulating nurse, should be requested to watch the visitors.

ASEPTIC TECHNIC

In the soft tissues, the forces of defense are much stronger and more rapidly mobilized than in the bones and joints. In the lower abdomen, a defense reaction is set up following irritation or infection and often so rapidly encapsulates the involved area as to protect the remainder of the abdominal cavity A similar situation is observed in other soft tissues In bone a reaction also takes place, but so slowly that the disease may cause irreparable damage before a practical degree of defense is established. In bone, moreover, a dormant infection is more easily relighted by a surgical procedure than in any other tissue, regardless of the length of time which may have elapsed after the subsidence of all active symptoms. Resistance is materially impaired as the structure of a bone in which there has been an infectious process is condensed and the circulation is deficient. Obviously a virulent infection in bones and joints is a real catastrophe, and a strictly aseptic technic is much more essential than in average general surgery

Many of the subsequent details of aseptic surgical technic may seem elaborate and unnecessary we, however, have found that attention to the most commonplace details by the entire personnel of a clinic, from the orderly or nurse who prepares the patient the day before operation to the assistant who applies the final dressing after operation is rewarded by a minimal number of postoperative infections.

In the Campbell Clinic, routine dressings of infected wounds are rarely applied by any of the operating room personnel. If so, rubber gloves are always worn to prevent contamination of the finger nails or hands and obviate the likelihood of carrying the infectious organisms to the operating room

Aseptic surgical technic is no stronger than its weakest link. In other words, the most minute details of a stated regime must be rigidly enforced This

begins with the surgeon himself, who must set an example for his assistants by adhering closely to the routine which he prescribes.

Preparation of the Hands

Preparation of the hands for surgery should be just as thorough as any other preparatory measure, and should never be neglected or performed in careless fashion. The forearms, beginning at the finger tips and continuing proximally to well above the elbow, should be scrubbed with a sterile brush in generous quantities of soap and water. Special attention should be given to all recesses between the fingers and around the nails. After four minutes of scrubbing the nails should be thoroughly cleaned with a sterile file under running water, then, with a second sterile brush, the scrubbing with soap and water should be repeated. During the entire process of washing and drying the arms should be held in a position which will cause the water to run from the fingers to the elbows; if the forearms and hands are allowed to fall in the dependent position at any time, contaminated water from the elbow will flow over the clean portions of the forearms and hands, thus defeating the purpose of the procedure. This step should consume ten minutes by the clock.

The choice of solutions for the arms and hands is a matter of individual opinion. A weak Lysol solution, sterile water and 70% alcohol, in given order, are effective. This part of the preparation of the hands is much less important than proper scrubbing.

Before putting on the gown and gloves, one should be sure that the arms and hands are thoroughly dry. Undoubtedly, solutions which creep through a gown are potential sources of infection, particularly about the elbows, as these regions must always be considered contaminated. If the proper procedure is not followed in drying the arms, however, the possibility of contamination is perhaps even greater. The process of drying should begin with the fingers and proceed proximally to the elbows. In drying the elbows, the towel is carefully folded so that the water will not soak through the several layers of the towel and contaminate the hands. The hands positively should not come in contact with the solutions removed from about the elbows.

Even after this careful preparation, the hands and wrists should not be allowed to touch any of the sterile equipment. If they come in contact with the outer surface of the gloves or an exposed portion of the gown, these should be changed.

When the operation is delayed, the gloved hands should be covered by a sterile towel, rather than folded across the chest beneath the axillae.

Local Preparation of the Patient

After application of the tourniquet, if one is required, the sterile preoperative dressings are removed. Care should be taken that the operative field does not become contaminated, as the effectiveness of the preparation will then be partially lost. With the patient in the proper position, the solutions used in the preoperative preparation are reapplied in the following order: benzine, ether, iodine, and alcohol. Each solution is applied by a separate sterile sponge stick. The immediate operative field is first prepared; *the area is then* gradually enlarged to include an ample portion of the surrounding skin. In

preparing the lumbar spine, for example, sponges are carried toward the gluteal cleft and anus, rather than in the opposite direction. The sponges should not be saturated otherwise, the solutions will extend beyond the operative field, necessitating their removal An excessive amount of iodine, even in the operative field, should be removed to prevent a chemical dermatitis. If the linen on the table or the sterile drapes become saturated with strong antiseptic solutions, they should be replaced by fresh linen.

Colored proprietary antiseptics commonly used in abdominal surgery are not suitable in surgery of the extremities when preparation of the toes or finger nails is involved. The majority of these solutions are difficult to remove, and the residual red pink, or orange color gives a false impression as to the status of the circulation.

For operations about the upper third of the thighs, pelvis, or lower lumbar spine in males, the genitals should be displaced away from the operative field and held in place by adhesive tape. A long wide strip of adhesive tape similarly aids in covering a potential source of infection the gluteal cleft. In females, the genital area and gluteal cleft are likewise covered longitudinally by strips of adhesive tape Before preparing the operative field in the region of the lower lumbar spine sacroiliac joint, or buttocks, the gluteal cleft is sponged with alcohol and a sterile dry gauze pad is inserted in the gluteal folds about the anus, that iodine or other solutions may be prevented from running down in this region and causing dermatitis.

In operations on the temporomandibular joint the auditory meatus should be cleansed and plugged with a small piece of sterile cotton

When these preparations are carried out in haste, the sterile assistant who is preparing the area may unknowingly contaminate his gown or gloves. To obviate such an occurrence, a nurse or the anesthetist should be delegated to watch this stage of the preparation

Draping

This is a most important step in any surgical procedure and should not be assigned to an uninitiated assistant Haphazard draping with resultant exposure of unprepared or contaminated areas of skin in the middle of an operation may cause a catastrophe. Considerable experience is required in placing the drapes, not only to prevent their becoming disarranged during *operation, but to avoid contamination of both the operator* and the drapes. If there is the least doubt as to the sterility of the drapes or the operator when draping is complete, the entire process should be repeated. Unless the operator has well trained assistants, he should drape the patient himself and should see that everything possible is done to insure sterile drapes and a sterile operative field.

In the 'foundation layer of drapes, towel clips are placed not only through the drapes, but through the skin, as a safeguard against slipping of the drapes and exposure of contaminated skin. In every case, the foundation drapes should be so placed as to overlap the prepared area of skin at least three inches. During this process, the gloved hands should not come in contact with the prepared skin

Foot and Ankle.—Two full-sized sheets are placed across the lower one-half of the table and the opposite extremity During this procedure, the

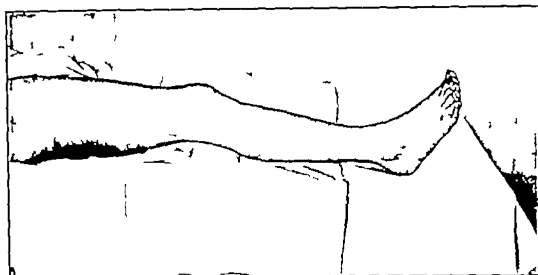


Fig. 33.—Draping of foot and ankle. Skin prepared from toes to just below knee. Foundation sheets and towel in place.

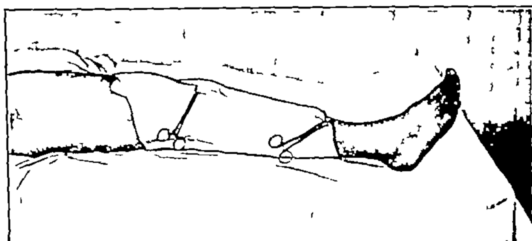


Fig. 34.—Leg enveloped in sterile towel. Towel clips include a portion of skin.

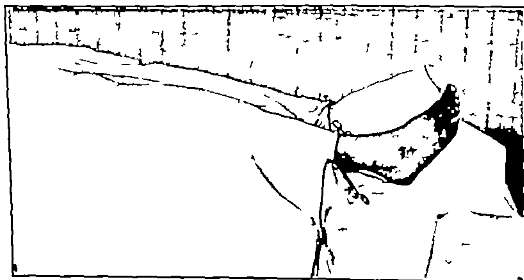


Fig. 35.—Top sheet fastened to drag sheet by towel clips.

nurse should stand with her back toward the head of the table and with outstretched arms, grasp the extremity just below the knee, to prevent the leg from dangling. A towel is then placed transversely across the table with its distal edge level with the middle third of the calf of the leg. The sterile assistant grasps the foot with a sterile towel as the limb is placed upon the table. The towel is folded snugly across the leg and fastened in place with two towel clips. A second double layer of sheets is then placed over the extremity so as to extend from a point just distal to the towel proximally over the body to the

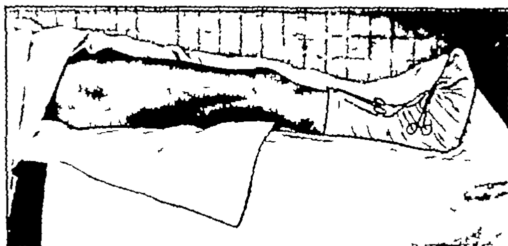


Fig. 36.—Draping of knee. Skin prepared from groin to ankle. Foot and lower leg enveloped in sterile towel. *Foundation sheets and towel in place.*



Fig. 37.—Foot and lower leg enveloped in sterile pillow case. *Upper towel surrounds thigh;* fastened in place by towel clips.

chin. A sterile pillow case or double sheet is next slipped transversely beneath the extremity and fastened with towel clips to the top or proximal sheet, drawing the two snugly together around the extremity. The pillow case or double sheet *forms a* drag which prevents exposure of contaminated areas when the knee and hip are flexed.

Knee.—*A double layer of foundation sheets* is laid across the lower half of the table and the opposite extremity. *They should extend from the* level of the gluteal fold distally well over the end of the table. A towel is

placed on the table longitudinally so that its upper end is level with the upper third of the leg and a second towel is laid on the table transversely at the level of the middle of the thigh The extremity is placed in the center of these two towels. The distal towel is folded about the foot, ankle, and lower half of the leg and fastened in place by two towel clips attached longitudinally The towel should be of sufficient width to cover the extremity completely and overlap several inches. With the aid of an assistant, the foot is inserted into a pillow

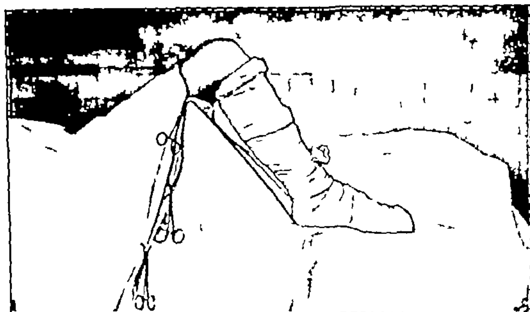


Fig. 38—Drapings of foot and leg rendered less bulky by snug application of sterile roller bandage. Drag sheet fastened at frequent intervals to top sheet, permitting wide range of motion of knee and hip without exposing unsterile field.

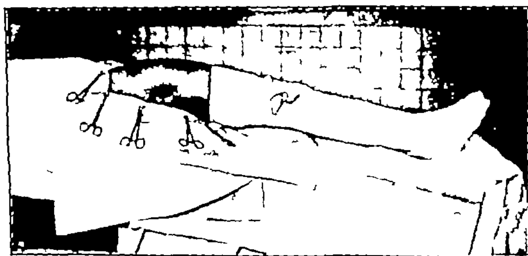


Fig. 39—Draping the hip. Lower extremity from groin to toes encased in sterile towels and sterile pillow case, these, in turn surrounded by sterile roller bandage. Operative field outlined by four sterile towels held in place by clips through skin at frequent intervals.

case and the edges of the case are held together with a towel clip In order to make a compact mass of these rather voluminous drapes, a sterile bandage is applied snugly from the toes upward to the proximal edge of the towel and pillow case The remainder of the drapes are placed as described for the foot.

Hip —The foundation drapes are applied as described for the knee, with the exception that two towels are placed longitudinally to envelop the limb

from well above the knee to the toes. The pillow case and bandage are then applied The operative area is outlined with four towels laid in a rectangular position and fastened by towel clips at intervals of two inches. The top sheet is placed transversely across the body with its distal edge well below the level of the prepared field. The gap between the foundation sheet and the top sheet is filled with two wide pillow cases fixed in place by numerous towel clips, both at the edge of the operative field and to the distal and proximal sheets.

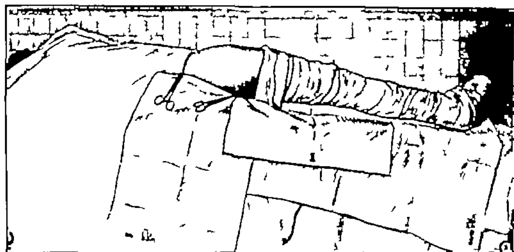


Fig 90—Interval between top sheet and foundation drapes covered by sterile pillow cases. Drag sheet on inner aspect of thigh in turn attached to sterile pillow cases with towel clips at frequent intervals, preventing exposure of perineum on abduction of hip.

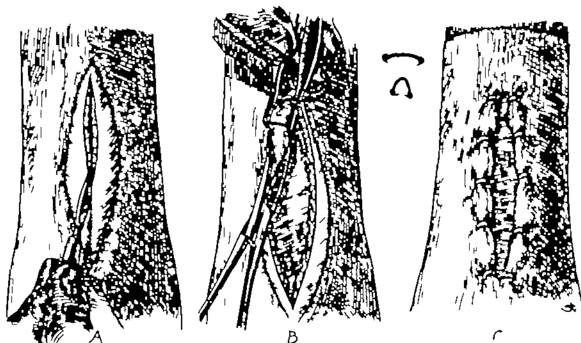


Fig. 91.—Draping of edges of skin incision. A Sterile stockinet incised in line of skin incision. B and C Stockinet overlaps edges of incision and is held in place by skin clips.

When one hip is ankylosed in adduction, the preparation is facilitated considerably by abduction of the unaffected extremity or by separation of the affected extremity from the opposite by compensatory side bending of the lumbar spine and pelvis. When both hips are ankylosed the patient is turned on his

side and the foundation sheets are slipped between the two extremities Care and dexterity are required to execute this procedure without contaminating the drapes.

Spine—Drapes for the spine are applied in a manner similar to that for abdominal operations, and require no special description

Upper Extremity—The shoulder, elbow, and hand are draped in a manner similar to that described for the hip, knee and ankle, respectively

Draping of the Edges of the Incision.—The gloved hand should not come in contact with the skin as the incision is made For the extremities, a section of sterile stockinet of appropriate size is drawn proximally over the incision. The stockinet is then grasped proximally and distally with hemostats and drawn taut, and with a skin knife an opening is made through the stockinet, of exactly the same length as the incision The skin knife is wrapped in a sterile sponge and laid aside The edges of the stockinet are then so placed as to overlap the skin incision and are held in place by skin clips or silk sutures applied at intervals of one inch

OPERATIVE TECHNIC

At the Campbell Clinic instrumental or so-called noncontact technic, is employed exclusively except in occasional operations limited to superficial soft structures or for infectious lesions, such as osteomyelitis.

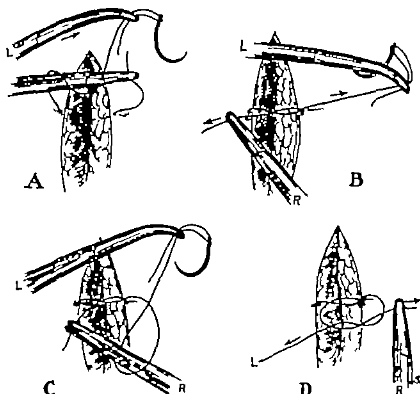


Fig. 92.—Square knot tied by instrumental technic. No assistant necessary

In noncontact technic, the following points are observed The table is set up ' entirely by means of instruments. Surgical needles are similarly threaded with sutures. All instruments are grasped only by the handles. On the surgical table and on the trays, the instruments are kept in order, that the

handles may not contaminate other instruments. In sponging or packing wounds, the sponge is not allowed to come in contact with the gloved hand. If, for any reason palpation is necessary a clean sterile glove is placed over the glove on the hand before the wound is explored. The use of the gloved hand in the open wound, however, is seldom required, as one becomes adept with the feel' of a hemostat. Ligatures for hemostasis and all sutures, with the exception of the final skin suture, are tied with forceps.

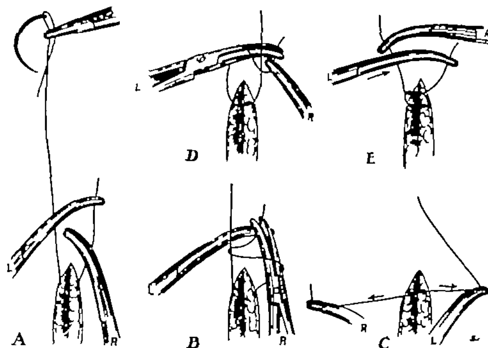


Fig. 93.—Square knot tied by instrumental technic. Assistant necessary

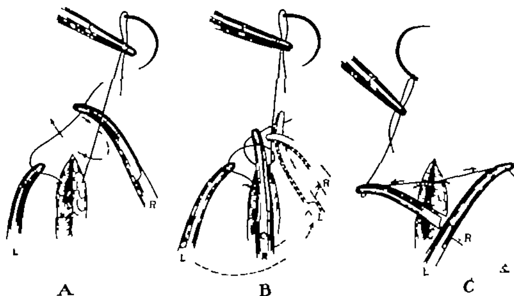


Fig. 94.—Variation of method illustrated in Fig. 93. Second portion of knot is reverse of A, B and C. Assistant necessary

Common sense dictates that there is no rule to which exceptions cannot be made. Undoubtedly many capable surgeons do not take such meticulous precautions, yet apparently obtain excellent results nevertheless, there can be

no argument that an absolutely sterile instrument is safer than the gloved hand in operations upon the bones. Instrumental technic when once practiced consistently, does not prolong the operative procedure

SPECIAL OPERATIVE TECHNICS

The following measures are utilized in a variety of procedures and are therefore described herein to obviate the necessity for repetition in subsequent chapters. The methods of tendon fixation and suture, internal fixation of bones, and bone grafting being particularly general in their application, are discussed in detail

TENDON FIXATION AND SUTURE

The principles of tendon surgery are described in the chapter on Affections of Muscles and Tendons, and under the subject of Tendon Transference in the chapter on Poliomyelitis. The following discussion deals only with the actual methods of uniting a severed tendon and of attaching one tendon to another or to bone.

Methods of Tendon Suture

End to End Silk Suture—Bunnell has described a classical method of suturing the severed ends of a tendon, whereby accurate end to-end apposition is maintained until the continuity of the tendon has been restored by fibrous tissue formation The procedure is carried out as follows

A small straight needle is threaded on each end of a silk suture While the tendon is held taut by means of a Kocher hemostat, the needle on one end of the suture is passed diagonally across the tendon one centimeter from the hemostat. Three similar stitches are taken backward and forward across the tendon, the needle entering the tendon a short distance beyond the immediately preceding point of emergence. The final stitch emerges two to three centimeters from the hemostat, but on the side of the tendon opposite from its first entrance.

The other end of the suture is passed transversely across the tendon and continued toward the hemostat with three diagonal stitches, emerging adjacent to the hemostat on the side opposite from the first suture. The traumatized tip of the tendon is then excised While the tendon is held taut by the finger over one suture, the other is passed through the substance of the tendon to its cut surface This procedure is repeated with the second suture. The sutures are drawn taut, removing all slack. The opposite segment of the tendon is similarly sutured and the opposing ends are tied.

The above method is also utilized in bridging defects of the tendons with tendon grafts.

Bunnell has modified this technic by continuing the silk suture first from one tendon end into the other tendon end. The slack is drawn out by pulling each strand separately, the tendon ends are then slipped down over the straightened strand into close contact A single knot is then tied and buried in the tendon at a distance from the line of juncture of the two ends and at a point which will receive the least strain.

End to-End Pull Out Wire Sutures (Bunnell)—*There are several advantages to this new Bunnell technic.* The stainless steel wire provides a suture

of minimum caliber and minimum reaction yet one which has ample strength. Since the suture is removable there are no retained elements to interfere with function of the tendon or to cause irritation

A stainless steel wire approximately one foot long and of the desired strength is threaded on straight needles, one on each end. The first needle is passed directly through the tendon about ⅝ inch from its end, then back and forth through the tendon four times, each time crossing just a few tendon fibers and progressing in this manner until it emerges from the tendon end. Care is exercised to prevent kinking or the wire may break or be difficult to remove

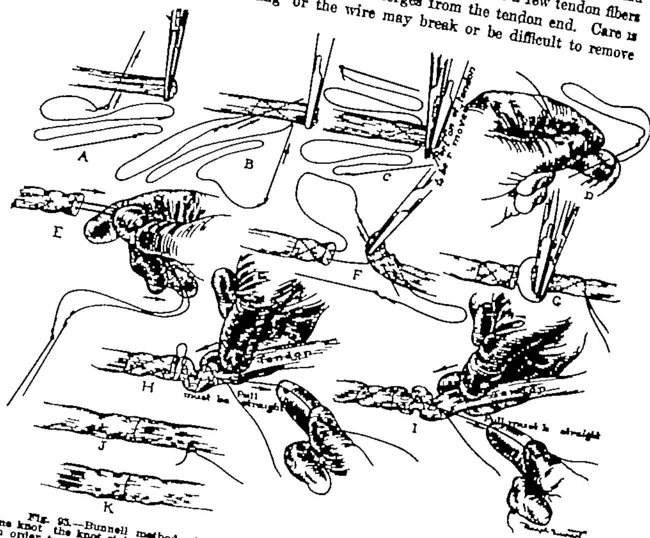


Fig. 93.—Bunnell method of suturing tendons with silk. By this technic, there is but one knot the knot sinks into the tendon and is placed at a point where it receives least strain. In order to prevent needle from spearing silk thread, both needles should be inserted simultaneously (From Bunnell, S. Surgery of the Hand Philadelphia, 1944 J B. Lippincott Co.)

later Before introducing the second needle a seven inch segment of wire is placed across the suture, to be used as a pull-out wire With the second needle the suture is then passed through the tendon in a manner similar to that of the first the second needle, however is passed through the tendon only three times. All slack is removed from the tendon by pulling the two ends of the wires. The two ends of the pull-out wire are now drawn together to form a loop Both ends of the pull-out wire are then threaded on a curved needle, passed up through the tendon sheath and out through the skin. The two suture ends are

Fig. 96.—Technic of Bunnell stainless steel wire pull-out suture. Pull-out wire should be twisted to avoid catching tissue in loop. The tiny double, right angle silk suture shown in *C*, *D* and *E* is rarely used. If main suture spears longitudinally down other tendon end an approximation suture is unnecessary. (From Bunnell, S. *Surgery of the Hand*. Philadelphia, 1944. J. B. Lippincott Co.)

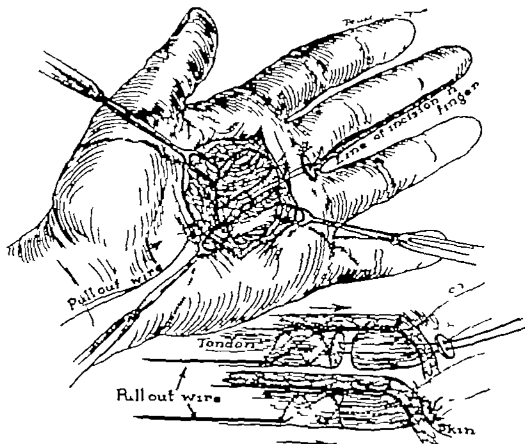


Fig. 97.—Bunnell technic of suturing a tendon in palm by a removable stainless steel wire. (From Bunnell, S. Surgery of the Hand. Philadelphia, 1944. J. B. Lippincott Co.)

passed down the center of the distal end of the tendon for at least an inch or more, the tendon being held taut with a Kocher clamp. The traumatized tissues at the ends of the tendons are excised. The sutures are then passed up the sheath a short distance, and then diagonally out through the skin for anchorage on a button crossbar through adhesive tape or through the finger nail as the case may require.

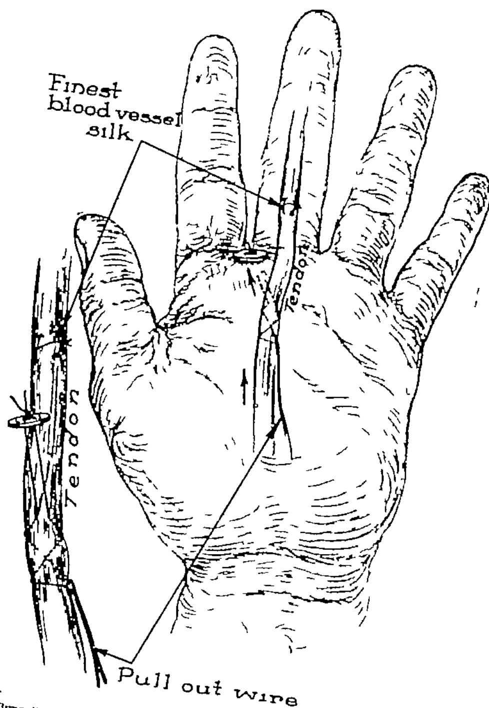


Fig. [illegible].—Bunnell end-to-end, pull-out suture at a distance. By placing stainless steel ire suture at a distance, adhesions in region of tendon suture are minimized. The method is articularly suitable for primary repai in narrow tunnels.

The sutures are ordinarily removed after three weeks The distal sutures are cut where they emerge from the skin, a tug is then exerted on the pull-out wire, thus withdrawing the sutures If any difficulty is encountered, rubber band traction is applied to the pull-out wire for a period of twenty four hours.

End to-End Pull-Out Suture at a Distance (Bunnell) —The technic of this suture is similar to that described above, but is accomplished proximal to the juncture of the cut tendon. Subsequently, the suture is passed down the tendon sheath and out the skin, and anchored distally The tension is just sufficient to approximate the tendon ends. The ends of the tendon are then maintained in position with a simple right angle stitch of the finest blood vessel silk The suture is not placed to prevent distraction but simply for approximation. By a "suture at a distance," the reaction of the tissues at the tendon juncture is minimized.

Suture of One Tendon to Another

In uniting one tendon to another as in tendon transference, the apposing surfaces of the tendons should be scarified to insure a rapid fibrous tissue fusion. The simplest method consists of apposing the tendons side to side and uniting

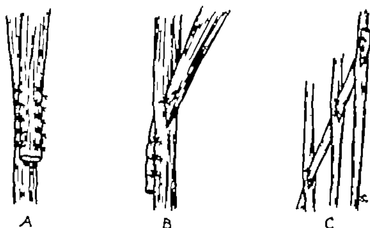


Fig. 99 —Method of uniting two or more tendons by interrupted silk sutures.

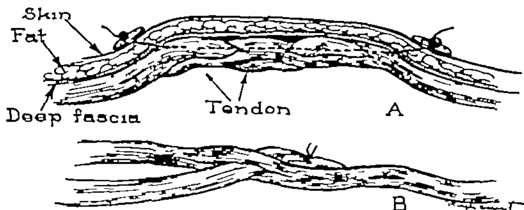


Fig. 100.—Bunnell technic of joining tendons one tendon entwines through the other Fixation is secured by a running wire suture Free tendon ends are buried. (From Bunnell, S. Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.)

their contiguous borders with interrupted sutures (Fig 99A) A firmer fixation is secured however if the transferred tendon is passed through a longitudinal aperture or slit in the intact tendon and attached distally by a side-

to-side suture (Fig 99*B*) Such a procedure is always carried out if the transferred tendon must be attached to two or more tendons (Fig 99*C*)

Removable Running Wire Suture for Side-to-Side Union (Bunnell) —This suture is used for joining lengthening, and shortening tendons. The tendon ends are tapered by a long oblique cut, and approximated. The steel wire suture is introduced through the skin proximal to the tendon juncture, passed back and forth through the overlapping tendon ends, and thence out through the skin distal to the tendon juncture The two ends of the wire are pulled taut and a shot is placed on each wire

Side-to-Side Suture by Interweaving the Tendons (Bunnell) —In splicing the tendons by this method, the splice may be held together by a removable running wire suture as described above.

Fixation of Tendon to Bone

In the fixation of a tendon to bone, the apposing surface of both bone and tendon should be scarified to insure rapid attachment Thus, the periosteum must be incised and elevated for a sufficient distance to expose the osseous surface and permit scarification. After completion of the tendon fixation, an attempt should be made to close the periosteum over the tendon, although, as a rule, this is impossible. Instead, the periosteum may be sutured to the edges of the tendon.

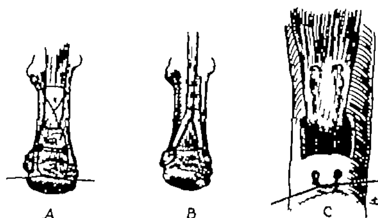


Fig. 101.—Fixation of tendon to bone.

The simplest method of tendon fixation consists of placing a suture in the end of the tendon by one of the technics described above By means of this suture, the tendon is pulled distally all slack removed, and the point of its attachment determined. Just distal to this point, a hole is drilled in the bone transversely The sutures on each side of the tendon are then passed through this hole in opposite directions and tied tightly over the shaft of the bone (Fig 101*A*) If the tendon is of sufficient length, the end is passed through the hole in the bone and sutured to itself (Fig 101*B*)

A broad, firm osseous attachment must be assured for the larger muscles, as illustrated in Fig 101*C* This method is advantageous in that a transverse drill hole through the shaft of the bone is unnecessary such a procedure is sometimes rather difficult in deep wounds and adequate exposure involves consider

able stripping of the soft tissues from the bone The method of fixing a tendon in the medullary canal is as follows After placing the suture in the end of the tendon and leaving two long free strands, a trap door is made in the bone, exposing the medullary canal at the predetermined point of attachment. Just distal to the trap door two holes are drilled through the cortex into the medullary canal The free ends of the suture are then passed through the trap door into the medullary canal and out through the two drill holes When these sutures are pulled taut the end of the tendon is drawn through the trap door into the medullary canal The trap door may be partially replaced, or broken into small fragments and packed into the defect in the cortex as minute grafts.

Fixation of Tendon to Bone (Cole) by a Stainless Steel Pull Out Suture—Because of the scarcity of soft tissue and the nature of the bone, this method is particularly applicable to the fixation of tendons into the dorsum of the tarsus, to the os calcis or to the phalangeal bones of the fingers (Fig 103)

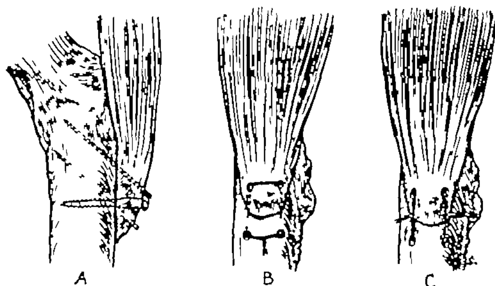


Fig. 102.—Fixation of osseous attachment of a tendon to bone. *A*, Fixation by Vitallium screw or nails. *B* Fixation by mattress suture of stainless steel wire through holes drilled in bone. *C* Fixation by wire loops.

The tendon is prepared and a pull-out suture is placed in the end of the tendon, as described for end to-end sutures (p 107) A small flap of bone is reflected with a chisel and, at the apex of the flap, a tunnel is drilled through the bone Both ends of the wire suture are placed on a long, straight skin needle The needle is passed through the hole in the bone and out through the skin on the opposite side, drawing the end of the tendon into the tunnel. The wire is then snugly anchored over a loop of gauze or a button. If considerable tension is anticipated, as in the tendo achillis, the skin should be padded with heavy felt and a cast applied with the wires protruding through the bottom of the cast After the plaster sets, the wire is anchored over a button on the outside of the cast.

Fixation of the Osseous Attachment of a Tendon to Bone.—In transferring larger muscles, such as the quadriceps, or the abductor muscles of the hip a firmer fixation is secured if the tendon is removed with a portion of its bony attachment. Sufficient bone is removed to present a cancellous surface The bony segment is drawn distally and the location of its reattachment determined

At this point the periosteum is elevated, the osseous surface of the shaft scarified, and the attachment of the tendon fixed to the raw area by two Vitallium nails driven in obliquely or by a Vitallium screw (Fig 102*A*) Wire loops, passed through holes drilled in the bone (Figs 102*B* and *C*), are also efficient. Silk or chromic catgut No 2 sutures are used instead of metal for fixation of tendons of the less powerful muscles If desired, a trap door may be made in the shaft of the bone and the osseous attachment of the tendon countersunk into the defect *and maintained by a suture as illustrated in Fig 101C*

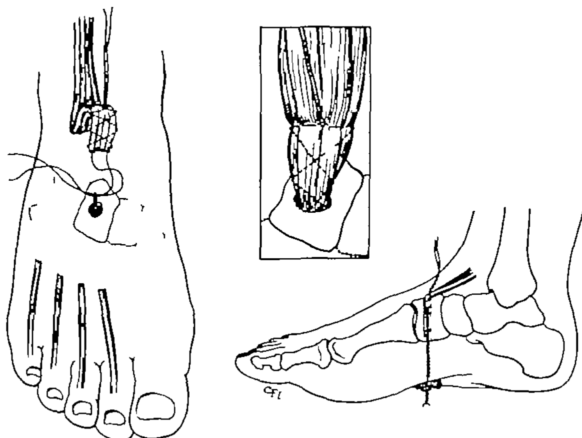


Fig. 103 —Cole s method of anchoring tendons to bone. The ends of wire suture are passed on a straight skin needle through a hole drilled in the bone. The needle is drawn through the skin on opposite side. Wire sutures are anchored over a rubber tube or a button. To obviate necrosis of skin when the suture is under considerable tension, the ends of the wire may be passed through bottom of a cast. Subsequently the wire is anchored over a button on outside of cast.

EXTERNAL SKELETAL FIXATION

There are several fairly standard and widely known types of external skeletal fixation apparatus. In the hands of a limited group this method of treat ment seems to work satisfactorily We cannot, however share their enthusiasm Our experience with a fairly substantial series of consecutive fractures has been *most disappointing in a large percentage slow unions or nonunions* followed. Perhaps in more adept and experienced hands, these objections are not valid. Regardless of one s dexterity the method has three disadvantages (1) the patient requires a great deal attention and care (2) hospitalization is relatively prolonged (3) the multiple pins which protrude through the skin into the bone present a constant threat of infection

INTERNAL FIXATION OF BONE

The following section deals particularly with methods of internal fixation of fresh, malunited and ununited fractures. The same measures, however, are suitable for maintaining position and alignment subsequent to osteotomy, leg shortening operations and other procedures.

The application of surgical principles to bone surgery embodies the minimum use of foreign material. Internal fixation, therefore, should be utilized reservedly. In many fractures, the ends of the fragments may be so placed as to provide relative stability without the introduction of foreign substances; in others, the fragments cannot possibly be maintained in position without some form of internal fixation.

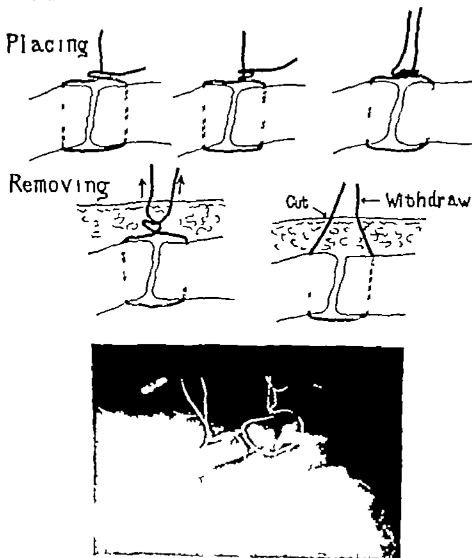


Fig. 104.—Bunnell technic of kink wire suture to reinforce fascial repair of acromioclavicular joint. A pull on each wire straightens out the kinks, thus permitting easy removal after three or more weeks. (From Bunnell, S.: Surgery of the Hand, Philadelphia, 1944, J. B. Lippincott Co.)

The general principles of treatment by open operation and the use of internal fixation as regards exposure, handling of the periosteum, and other details of technic are described elsewhere (p. 361).

Metallic materials should be considered only as temporary means of producing immobilization and stability, not as a substitute for the stability of the

normal anatomic structures If bones do not unite, the metallic fixation must inevitably bend, break, or pull out.

Sutures.—In the strict sense of the word autogenous materials such as tendon and fascia are seldom used alone as suture material. Because of their tendency to stretch autogenous material must usually be reinforced, at least temporarily by a more rigid form of fixation (Fig 104) Tendons and fascia are most often used in operations for dislocations of the sternoclavicular acromioclavicular or shoulder joints, to provide artificial ligaments, or to reconstruct ruptured ligaments.

If long narrow strips of fascia lata are desired for suture material, an unsightly scar may be prevented by the use of a fascia stripper A short longitudinal incision is made over the lateral surface of the thigh just distal and anterior to the greater trochanter *A small tonguelike flap of fascia lata of the* proper width is dissected up inserted through the eye of the stripper and grasped at its end with a hemostat. The stripper is then continued subcutaneously until the proper length of the fascia is elevated and the flap is severed and withdrawn.

When a tendon is desired for suture material, a section of the peroneus longus, palmaris longus, or the extensor tendon of the fifth toe provides an excellent source.

The strength of such materials as catgut, silk, or nylon limits their usefulness for fixation of fractures to relatively minor roles.

Stainless steel wire sutures of a size sufficient for the requirements of the case have a wide variety of application, though the limitations of stability by this procedure should be recognized. Sutures placed through holes drilled in bone are not satisfactory for absolute and positive immobilization Apposition may be maintained, yet angulation may follow

The drilling of holes in a position which permits the passage of sutures is exceedingly difficult in some locations Wire, as a rule may be readily inserted through holes in bone whereas nonrigid material such as catgut or silk, or fascia lata must be drawn through by means of wire loops or tendon carriers passed through the holes from the opposite direction.

Because of these objections, wire sutures are seldom applicable to diaphyseal fractures rather their use is limited chiefly to approximation of fractures wherein a segment of bone together with a tendon is avulsed as, for example, the circumferential wire loop employed for fractures of the patella (p 409) and the figure-of-eight wire loop for fractures of the olecranon (p 489)

Bone Pegs, Wire Pins, Transfixion Screws, Bolts.—This group of apparatus is particularly suitable for the following purposes (a) to fix one or more small fragments together or to a large shaft fragment in the region of a joint, or the metaphyseal portion of a bone (Fig 298) (b) to transfix torsional, long oblique, or butterfly fractures of the shaft of a bone (Fig 273) (c) to transfix an avulsion fracture or to re-establish the bony insertion of a tendon in a new location (Fig 102)

An elaborate array and variety of equipment is unnecessary For the smaller pins, segments of Kirschner wires or rods the size of a Smith Petersen guide pin are adequate. If a threaded pin is desirable, the ordinary standard screws employed with Venable plates, Blount plates, or Neufeld nails are satis-

factory If a lag screw effect is desirable the Knowles' pin is suitable If additional compression effect is necessary, the Knowles' pin may be converted into a bolt by the addition of a washer and nut

Bone pegs are now seldom employed primarily for fixation Intramedullary wires have practically eliminated their use, even as intramedullary bone pegs for metacarpal and metatarsal fractures.

A threadless pin should not be inserted at a right angle to the fractured surface In the event of absorption about the pin, this might lead to displacement of the fragments Further the introduction of the pin at a slightly oblique angle provides more secure fixation If more than one pin is necessary these should ordinarily, be placed at a slight angle to each other rather than parallel This type of fixation is chiefly applicable to fractures about the elbow in children

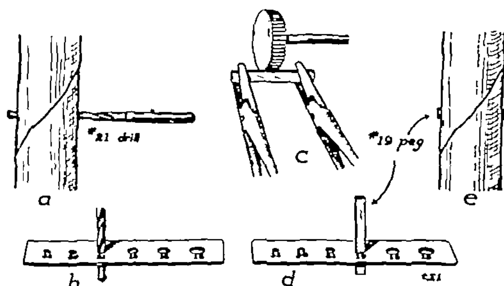


Fig. 10.—Bone peg would no longer be used for oblique diaphyseal fracture, as illustrated. Method of preparing bone pegs, however is correct. For a No. 21 hole in the bone, the peg should be milled to fit tightly into a No 19 hole in the gage.

The technic for insertion of a metal pin or nail requires little description The pin is grasped by a hemostat and held in position if the wound is deep an inlay will facilitate the process of insertion Or if preferred the wire or nail may be drilled into place. If removal of the pin or wire is contemplated at least ⅛ inch of the end should protrude beyond the surface of the bone otherwise, the end may be covered by callus and located with difficulty at a later operation

Threaded pins, screws, or bolts provide a much more stable fixation Standard screws are inserted in ⅛ inch holes in hard bone and 7/64 inch holes in cancellous or osteoporotic bone For the insertion of the larger threaded pins such as the Knowles pin drill holes are unnecessary

Plates and Screws—Plates and screws have a wide *application to fractures* of the shaft of the long bones (Fig 270) Their use has become so commonplace that the style of the plates and the size of the screws is relatively standardized Whether the material is Vitallium or 18-8 S Mo stainless steel makes little difference though the two should not be mixed The width and length of the plate should be commensurate with the size of the bone and the

stress to be placed on the plate subsequently In smaller bones, four screws provide ample fixation two-screw plates should not be used, as the plate merely serves as a hinge allowing angulation In the larger bones, such as the femur and, occasionally the tibia, as many as six screws may be required. The two screws nearest the center of the plate should be at least ½ inch from the ends of the fragments. The details of technic of application of a plate and screws to a bone are described on p 364

Special Plates and Nails—It is not the purpose of this section to describe in detail all of the ingenious gadgets that have been devised for the purposes of internal fixation. Such a section would indeed be encyclopedic in size.

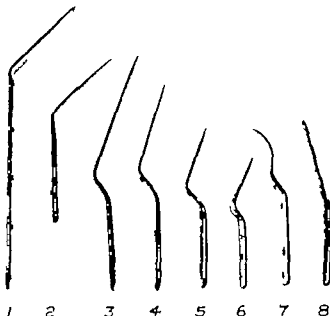


Fig. 166—Types of blade plates 1 Moore single angle blade plate for subtrochanteric fracture. 2 Moore single angle blade plate for trochanteric fracture. 3, 4, 5, 6 Blount double-angle blade plate for high femoral osteotomy 7 Curved-on the-flat blade plate. 8. Straight blade plat bent for fixation of McMurray osteotomy according to technic of Neufeld. (Courtesy of Dr W P Blount.)

In addition to the routine orthopedic appliances, special types of nails and plates are a necessary part of an orthopedic armamentarium. Many of these are designed for one particular job for example, a Smith Peterson nail is immediately linked with fractures of the neck of the femur Other appliances originally designed for a particular procedure *however may be adapted to a* variety of uses. The Blount or Moore blade plate is an example. This appliance may be utilized for any fracture from the base of the neck of the femur through the subtrochanteric region (Moore plate) or for fixation of osteotomies or leg shortening operations in the same region (Blount plate) *By changing* the angle, one may employ it for high or McMurray type osteotomies (p 676) On conversion to a right angle the blade provides an excellent means of fixation of supracondylar fractures of the femur (Fig 298)

Intramedullary Fixation.—Metallic *intramedullary fixation of bone is a* relatively new procedure, and has not yet been generally adopted in this country A sufficiently large series of cases have not been reported to permit a true estimate of its value. The method has been variously advised for fresh, mal

united, ununited or pathologic fractures, or as a means of fixation following osteotomy or leg-shortening procedures. Until we have formed a more definite idea of its limitations, advantages and real value, we expect to limit its use primarily to fresh fractures (p 367)

Bone Grafts—Autogenous or homogenous grafts are used as an ideal means of combining fixation with osteogenesis, and are indicated in preference to other forms of fixation for fractures wherein slow union is likely, for example, in comminuted fractures of the middle and proximal thirds of the ulna and the distal and middle thirds of the radius. The use of grafts in fresh fractures will probably be expanded now that homogenous bone is readily available. For an established nonunion and for malunion in certain locations, a bone graft is ordinarily the best form of fixation.

BONE GRAFTING

The principles, indications, and technic of bone-grafting procedures were well established before the metallurgic age" of orthopedic surgery Because of the necessity of using autogenous materials as bone pegs or, in some cases wire loops, fixation of grafts was at best rather crude. Lane introduced internal fixation, Albee Henderson, Campbell and others added osteogenesis to this principle to develop bone grafting for nonunion into a practical procedure The two principles, fixation and osteogenesis, were not however efficiently and simply combined until Venable and Stuck initiated fixation by inert metal screws. At this stage, it seemed that bone grafting had more or less reached its peak of efficiency Now comes the bone bank with its obvious advantages. Who knows what the future may hold?

Indications for Bone Graft

Bone grafts may be utilized for the following purposes

1 To eradicate cavities or defects from cysts, tumors, or other causes.
2. To bridge joints, and thereby provide arthrodesis
3 To bridge major defects or establish the continuity of a long bone.
4. To provide bone blocks to joint motion in stabilization procedures.
5 To establish union in a pseudarthrosis.
6 To promote union provide fixation or fill defects in delayed union mal union fresh fractures, or osteotomies

Structure of Grafts

The structure of grafts may be expressed in an equation, as follows Cortical bone is to fixation as cancellous bone is to osteogenesis. It is true that fixation and osteogenesis may be combined this is one of the prime advantages in using a bone graft These two factors, however vary with the structure of the bone. Probably all or most of the cellular elements in grafts (particularly cortical grafts) die and are slowly replaced by creeping substitution the graft merely acting as a scaffold for the formation of new bone In hard cortical bone this process of replacement is considerably slower than in spongy or cancellous bone. While cancellous bone is more osteogenic on the other hand, it is not strong enough to provide efficient fixation In selecting the graft or

combination of grafts for any individual case the surgeon m of these two fundamental differences in bone structure. C amalgamated with the host, and is sufficiently strong to pe use of the part, a metamorphosis of the bone structure takes pla with functional demands.



Fig. 107.—Cross section of cortical bone, showing Haversian sy



Fig. 108.—Cross section of cancellous bone.

Fate of Grafts

tenets to cortical bone grafts, it can be readily understood that little osteogenetic power can be expected since this type of graft is composed almost entirely of mature osseous elements which will not survive. Thus, the cortical graft serves as a relatively inert, internal splint which may eventually be replaced by new bone This process can take place only after the entire mass has undergone revascularization, autolysis of the collagenous scaffolding and a revision of the mineral elements *The relatively compact nature of cortical* bone with small Haversian canals provides inadequate pathways for the invasion of capillaries and their accompanying cellular elements. For osteogenesis from the cellular elements of the capillary cuffs, an accommodation space must be available. This space is provided only after the original collagenous elements have been removed Consequently new bone is likely to be laid down around the graft, incorporating the graft instead of the graft becoming the immediate site of new bone formation Since the formation of new vessels reaches its peak within a few days after the operation and subsequently declines, penetration of the graft may cease before portions of the graft remote from the vascular bed obtain a vascular supply

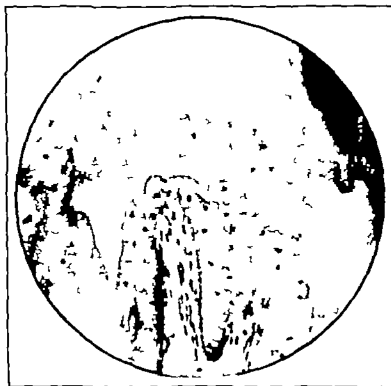


FIG. 109.—Photomicrograph showing reorganization of a bone transplant. (From Phemister D. B. J. A. M. A. 64 211 1915)

Abbott and others pointed out that in cancellous bone the mature bone elements do not survive, and herein lies the difference from cortical bone transplants each of the trabeculae has an endosteal surface and there are numerous marrow spaces. Pathways for new vessels and the subsequent newly formed bone are provided by the rapid degeneration of bone marrow cells. Rapid revascularization insures survival of the endosteal cells and early osteogenesis. New trabeculae mingle with the old the latter lying in *such close* relationship to vital elements as to facilitate removal and rapid replacement

Abbott and others also point out that cancellous bone with a high fat content as that removed from the upper tibial metaphysis and lower femoral metaphysis, *has less osteogenic qualities than bone containing red marrow with a minimal* of fatty content, such as the ileum In the final analysis the superior osteogenic qualities of cancellous bone arise from the extensive endosteal *surfaces and the* numerous accommodation spaces which allow early revascularization and osteogenesis. (For more details as to the fate of the graft, the reader may well refer to the article by Abbott Schottstaedt, Saunders, and Bost.)

Source of Grafts

Autogenous Grafts.—When a patient is his own bone donor the grafts are usually *removed from either the tibia, fibula, or ilium. These three bones* provide cortical grafts, whole bone transplants and cancellous bone respectively

Strength is a necessary requisite in a graft which is to be used for bridging a defect in a long bone, or even for the treatment of a pseudarthrosis. The extensive subcutaneous anteromedial aspect of the tibia provides an excellent source for these grafts. In adults, after removal of a cortical graft, the condyles of the tibia supply a rather substantial amount of cancellous bone. Apparently *there is no advantage in leaving the periosteum attached to the graft.* There are some definite advantages, however, in suturing the periosteum over the defect. The periosteum seems to serve a useful purpose in the leg as a limiting membrane to prevent an irregular formation of callus when the defect in the tibia fills in with new bone The few bone cells which are stripped off with the periosteum may assist in the formation of bone to fill the defect

There are some very real disadvantages to the use of the tibia as a donor area (1) a normal limb is jeopardized (2) *removal of the graft adds to the* length and magnitude of the procedure, (3) hospitalization and convalescence are prolonged, and ambulation must be delayed until the defect in the tibia has partially healed, (4) the tibia must be protected from six months to one year to prevent fractures.

The entire proximal two-thirds of the fibula may be removed without materially disabling the leg The anatomic configuration of the proximal end of the fibula presents a distinct advantage the *proximal end* presents a rather rounded prominence, which is partially covered by hyaline cartilage, and thus *forms* an ideal transplant to replace the distal third of the radius or the distal third of the fibula. After transplantation, the hyaline cartilage probably degenerates rapidly into a relatively poor fibrocartilaginous surface even so this surface is preferable to raw bone.

Homogenous Grafts.—A homogenous graft is one obtained from a human donor other than the patient. *If the graft is removed from an immediate* relative the term syngenesioplastic graft is appropriate.

Prior to the development of the bone bank (see below) homogenous grafts were used only when autogenous grafts were not available or there were definite objections to their use. In small children, the ordinary donor sites do not provide cortical grafts of sufficient dimensions for bridging defects, or a sufficient quantity of cancellous bone may not be available to eradicate a large cavity or cyst further *the possibility of* violating an epiphysis or pro-

ducing deformity or growth disturbances must be taken into consideration Heretofore, under these circumstances, the grafts were ordinarily removed from the father or mother

Blood type or Rh factors have no bearing upon the use of homogenous bone The donor however, should be in good health, and should be examined for malaria and syphilis.

Heterogenous Bone Grafts—As an answer to some of the undesirable features of autogenous and homogenous bone *grafting, heterogenous bone, i e,* that from another species, was tried in the early stages of bone grafting and found to be almost universaly unsatisfactory Beef bone, cow horn and other grafts were tried The heterogenous material retained, more or less its original form, acting only as an internal splint and did not stimulate bone production any more than catgut or kangaroo tendon sutures. As a matter of fact, these so-called grafts served as foreign bodies, often inciting a reaction and undesirable sequelae.

Bone Bank

Prior to the development of the bone bank it was our opinion that autogenous grafts were more satisfactory than homogenous grafts. We can certainly say that these were general impressions and not based upon facts derived from experimental data. Until recently, orthopedic surgeons had little reason to be particularly interested in any kind of homogenous graft This was a natural course of events in the premetallurgic era of orthopedic surgery autogenous materials were widely employed and the technics of autogenous bone grafting were developed to a high state of efficiency By the onlay bone graft procedure union could be induced in more than 90 per cent of pseudarthroses of the long bones, for this reason it was natural that little interest should be manifested in homogenous grafts

For other than scientific reasons, the *use of homogenous and syngenesioplastic* grafts was unpopular Removal of massive cortical grafts is a major surgical procedure the period of disability is long and sometimes may be permanent, hence the supply of fresh homogenous bone is justifiably limited Fresh homogenous bone is an ideal solution for the recipient, but it is not a comparable experience for the donor

The use of refrigerated homogenous grafts now offers a practical solution to many difficult reconstruction problems From a study of both autogenous and homogenous cortical bone transplants, all are agreed that few of the mature elements of the bone survive transplantation. Hence theoretically, there should be little difference in the take of an autogenous a fresh homogenous or a refrigerated homogenous graft Our clinical experience would not entirely confirm this assumption

The supply of homogenous bone is inexhaustible, and apparently grafts will keep indefinitely under proper refrigeration When thawed for use in an operation they are similar in appearance and physical characteristics to fresh bone

To the present time technical information regarding the bone *bank is at best* sketchy In general our bone bank has been established according to the tenets outlined by L. F Bush The reader is referred to his article for details of preparation of the bone and freezing and preserving the grafts. So far we

have had relatively little trouble in maintaining an adequate supply of bone in the bank from excess bone removed in selected, clean, surgical cases, syngenesioplastic donors, and from amputated specimens. The tibia and fibula have been preserved from specimens amputated for Buerger's and other vascular diseases. Eight months' experience with the bone bank hardly permits us to make a definite statement at present, though the results so far have been sufficiently gratifying to suggest that *the method holds great promise for the future*.

Massive refrigerated grafts have been used in 30 patients for the following conditions

Internal Fixation for Fresh Fractures.—The use of metallic internal fixation, particularly in fractures of both bones of the forearm, has been attended by a disappointingly high *percentage of nonunions*. *Refrigerated homogenous* cortical grafts, in a measure, eliminate some of the fundamental objections to metallic internal fixation. In addition to being a satisfactory stabilizing agent, *an osteogenic factor has been provided*; *this* is a definite advantage in any area where union is slow or nonunion is common

Fillage and Massive Grafts for Defects.—The majority of data which has been accumulated so far refers particularly to the use of small grafts in bone cysts, giant cell tumors, or as a means of reinforcing arthrodeses. With a favorable result from these procedures, we felt justified in expanding the use of refrigerated grafts to massive transplants of homogenous cortical bone, and even whole bone transplants to span gaps in ununited fractures. Clinical or roentgenologic *data of a limited number of cases would indicate that there is very* little difference in the reaction of homogenous and autogenous grafts. In several instances of dual bone grafts we have utilized a fresh autogenous bone graft on one side and a refrigerated homogenous graft on the other. Subsequent roentgenograms during the first few months postoperatively have revealed no distinguishable difference in their appearance. Sufficient time has not elapsed to make final conclusive statements as to an ultimate comparison between the two types of grafts. Studies are now under way which in the not too distant future should provide answers to these problems.

Spinal Fusion.—For many years two-stage bone grafting procedures have been utilized wherein the graft was removed at the first stage and preserved *at ordinary refrigeration temperatures* for periods of two weeks or longer prior to fusion of the spine. Clinical experience has proved that this type of grafting procedure has been entirely satisfactory. These grafts have been incorporated and amalgamated with the *host bone in the same manner as fresh* autogenous materail. In a limited number of cases, in lieu of fresh autogenous bone, we have utilized both cortical and iliac grafts from the bank. The number of these cases, the short period of postoperative observation, and the difficulty of proper roentgenologic visualization of the progress of the grafts necessarily limits any conclusive statements as to the efficiency and efficacy of refrigerated homogenous grafts for lumbosacral fusion.

Indications for Various Technics of Bone Grafting

Single Onlay Cortical Graft.—The onlay bone graft (p 619) is the simplest and most effective means of treating the majority of ununited diaphyseal frac

tures. Usually, the fixation secured by the cortical graft is supplemented by cancellous bone for osteogenic purposes The same type of grafting procedure is applicable to a limited group of fresh fractures, malunited fractures, or following osteotomies.

Aside from their use in diaphyseal lesions cortical grafts are also utilized in bridging joints to produce arthrodesis, not only for osteogenesis, but also for fixation. The popularity of a cortical graft, as exemplified by the Albee procedure for use in fusion of the spine has waned during the past few years in favor of the more osteogenic bone from the ilium

Dual Onlay Bone Graft.—The advantages of a dual onlay bone graft are apparent especially in the treatment of difficult and unusual nonunions or in the bridging of massive defects (p 625) Nonunion of a fracture near a joint is difficult to treat in that the distal fragment is generally osteoporotic. The joint fragment is largely cancellous, having only a thin cortex, and is often so small that fixation with a single graft is impossible Screw threads will not hold well in the soft bone and wire sutures tend to cut through the bone With a dual graft, a forcepslike action may be obtained providing relatively good stability In elderly individuals whose bone is osteoporotic, nonunion of a shaft fracture should be treated by a similar method.

In bridging defects the advantages of the dual graft are as follows (1) mechanical fixation is better than by the ordinary single onlay bone graft (2) the two grafts insure added strength and stability the diameter and dimensions of the graft being proportionate to those of the grafted bone, (3) the two grafts form a trough into which cancellous osteogenic elements may be packed (4) during the healing process, the tibial grafts prevent the compression of the transplanted cancellous bone by contracting fibrous tissue usually observed following the use of a single graft. After a large defect in the lower extremity is bridged by a dual graft protection from full weight bearing is necessary over a long period of time. Consequently if shortening is not too great a factor the defect should be obliterated and the ends of the fragments opposed before the grafts are applied.

Except in the presence of osteoporotic bone or a nonunion near the joint a whole fibular graft is usually superior in the upper extremity to a dual onlay graft.

Inlay Graft.—By the inlay technic, a slot or rectangular defect is created in the cortex of the host area (p 630) usually by means of a dual saw A graft of similar or slightly smaller dimensions is then fitted into the defect In the treatment of diaphyseal nonunion the onlay technic is far simpler and more efficient and in the hands of most surgeons, has replaced the inlay graft The procedure still has a limited application to arthrodesing procedures particularly the ankle (Chapter XV)

Peg Grafts—Peg grafts may ordinarily be considered as an innocuous means of internal fixation (p 116) rather than as a means of osteogenesis. Since the strength of the graft is limited in comparison with metallic fixation the method is limited largely to such conditions as nonunion of the internal malleolus of the ankle and to a few fractures of the neck of the femur

Intramedullary Grafts—Intramedullary grafts were tried in the early stages of the development of bone-grafting technics for nonunion of diaphyseal

fractures. Mechanical fixation was insecure and, in some cases, led to unusual complications In one case, a tightly fitting graft interfered with the circulation to the ends of the fragments to such an extent that a complete ring sequestration of the cortex followed Callus, while exuberant, was generally of poor quality and formed in much the same manner as involucrum about a sequestrum. These peculiar reactions in callus formation and sequestration are observed in some degree following metallic intramedullary fixation (p 367) The use of intra medullary grafts is practically limited to the metatarsal and metacarpal bones, and to the distal end of the radius.

Osteoperiosteal Grafts.—The *osteoperiosteal graft was designed to provide osteogenesis* for an irregularly curved surface as, for example, in the fusion of a scoliotic spine. This type of graft, however is less osteogenic and less *efficient than multiple cancellous grafts*

Multiple Chip Grafts—Cancellous Grafts.—Multiple chip grafts or cancellous grafts have a wide application Segments of cancellous bone represent the most efficient osteogenic material available In the ilium, we have practically an inexhaustible source Cancellous bone is particularly useful in eradicating cavities or defects from cysts, tumors, or other causes, for establishing bone blocks, or for wedging in osteotomy sites Being rather soft and fragile, this bone is relatively easy to press into any nook cranny or crevice If slight rigidity and strength are desirable the cortical elements of the ilium are retained.

In practically all bone-grafting procedures wherein cortical bone is utilized for fixation, supplementary cancellous bone or chip grafts are employed to promote union and early healing Because of the minimal mechanical requirements and the maximal osteogenic requirements, cancellous grafts are particularly applicable to arthrodesis of the spine

Hemicylindrical Grafts.—These grafts are suitable for obliterating large defects of the tibia and femur Massive hemicylindrical cortical grafts from the *affected bone are apposed across* the defect and are supplemented by cancellous iliac bone A procedure of this magnitude is applicable to only a limited group of cases (p 708)

Whole Bone Transplant.—The *fibular graft affords* the *most* practicable means of bridging long defects in the diaphyseal portion of the bones of the upper extremity provided the nonunion is not too close to a joint. Mechanically a fibular graft is stronger *than a full thickness tibial* graft with an equivalent amount of cortical bone, just as a pipe is stronger than a rod made of the same amount and weight of material. In some cases, when soft tissue is scant, the *wound may be closed over a fibular graft* when closure over a dual graft of comparable strength would be impossible. The removal of a fibular graft weakens the leg less than the removal of the large tibial grafts.

In children the *fibula may also be used to span* a long gap in the tibia, ordinarily by a two-stage procedure (p 716) The normal configuration of the upper end of the fibula provides a thoroughly satisfactory substitute when the *distal end of the fibula or* the distal end of the radius must be resected (Chapter XIX)

Conditions Favorable for Bone Grafting

Certain conditions are necessary requisites to the successful consummation of a bone-grafting procedure If a high percentage of "takes" is to be secured, moreover certain principles must be followed in the execution of the operation

The primary consideration is the provision of a vascular soft tissue investment and a vascular host bone Avascularity is more than a theoretical contingency Aside from infection it is the most common cause of failure of bone grafting procedures Provision of this vascular bed begins with the preoperative treatment When feasible exercises of the adjacent joints, set up exercises of the muscles, and regular massage of the extremity improve the circulation of the limb as a whole Extensive scars over the operative site, particularly over superficial bones such as the tibia must be eliminated by previous plastic repair At operation, excessive scar tissue about the fracture site must be resected until a soft tissue vascular bed is reached Similarly the scar tissue should ordinarily be resected from between the ends of the fragments to permit apposition of vascular raw surfaces of bone

Because of previous sepsis or many operations, sclerosis or avascularity of the bone may extend two or three inches from the fracture site. When the area of avascularity is limited to the immediate ends of the fragments, resection is a practicable solution particularly in the upper extremity In the tibia and femur however excessive shortening is not desirable In some cases, we have resected an extensive degree of avascular bone and bridged the defect with a bone transplant rather than attempt an onlay bone-graft procedure with the avascular ends apposed

The ends of the bone must be cut at exact angles, and the cortices of the fragments must be shaved and flattened so as to provide the maximum contact between the host bone and the graft. In the grafting of long bones with cortical bone, firm fixation is desirable to maintain the contact and alignment of the fragments and maximum contact of the graft to the host bone. Inert metal screws are suitable for this purpose

During bone-grafting procedures, surgical principles must be observed in detail (p 613) More than ordinary care is necessary in suturing the wound in order to provide the widest possible contact between the vascular soft tissue and the graft and host bone

One should not rely too strongly upon the strength and stability of internal fixation by cortical grafts. Casts or other means of external fixations must be maintained until union of the fragments is well advanced and the graft has united with the host

Preparation of Grafts

Technic of Removal of Tibial Grafts.—To avoid excessive loss of blood from the bone tibial grafts should be removed under a tourniquet, preferably the pneumatic type (p 61) Following removal of the graft air may be released from the pneumatic tourniquet without disturbing the surgeon or sterile drapes.

A slightly curved longitudinal incision of proper length is made over the anteromedial aspect of the tibia, being placed so as to prevent a painful scar

over the crest. Without reflection of the skin the periosteum is incised to the bone. With a *periosteal elevator* the *periosteum is* then reflected medially and laterally, exposing the entire expanse of the tibia between the crest and the medial border. If this procedure is executed carefully the thin friable periosteal membrane may be closed following the operation. To provide better exposure at the extremities of the incision, the periosteum is incised transversely, thus, the incision through the periosteum is shaped like an I.

SECTION #3
Level of tibial tubercle

SECTION #7
Level near junction of upper and middle thirds of the tibia

SECTION 101
Level near junction of middle and lower thirds of the tibia

Fig. 110.—Cross sections of leg, showing line of approach for removal of whole fibula transplants, or tibial grafts. Shaded segment shows portion of tibia to be removed. Note that thick, strong angles of tibia are not violated. (From Boyd, H. B.: Lectures on Reconstruction Surgery, Ann Arbor, 1940, J. W. Edwards Publisher. Cross section from Eycleshymer, A. C. and Schoemaker, D. M., New York, 1930, D. Appleton and Co.)

In cross section, the tibia is more or less triangular in shape, the angles being represented by the anterior, medial and lateral borders Architecturally, these angles constitute the strongest portion of the tibia, the metallurgist uses the same principle to reinforce metal by crimping Ordinarily the borders of the tibia should not be violated The exact length and width of the graft should be determined and outlined on the cortex with an osteotome This is a necessary requisite to good craftsmanship an accurate pattern is particularly necessary if a curved graft is to be cut The outline of the graft is then cut with a motor saw, and a few taps on an osteotome at the extremities of the graft complete the procedure As the graft is pried from its bed an assistant should grasp it firmly lest it catapult to the floor Prior to closure of the wound, additional cancellous bone is removed from the proximal end of the tibia with a curette. Care should be taken to avoid the articular surface of the tibia, or, in a child, the epiphyseal line.

If the periosteum is relatively thick and has not been detached so that it rolls on itself suture of the incision may be possible without any defects As a rule this membrane is thin and friable and closure may not be perfect or exact.

If the graft has been properly cut little shaping or readjustment is necessary It is our practice to remove the endosteal side of the graft This is undertaken for two reasons the thin endosteal portion provides a graft with osteogenic potentialities to be placed across the fracture site parallel to and on the opposite side from the cortical graft further the endosteal surface being rather rough and irregular should be removed to insure a uniformly smooth cortical surface for contact with a uniformly smooth bed

Removal of a Fibular Graft.—In the removal of a fibular graft three points should receive particular consideration (a) care should be exercised to avoid damage to the peroneal nerve (b) sufficient bone must be left to insure a stable ankle (the lower one-fourth) (c) the graft should be removed without cutting the peroneal muscles.

For the average grafting procedure the middle third or the middle half of the fibula is resected through a Henry approach (p 172) If the transplant is to substitute for the distal end of the radius or distal end of the fibula, the proximal limb of the Henry approach is utilized after the resection is complete the biceps tendon is sutured to the adjacent soft tissues. Dissection in the middle third of the leg is carried along the anterior surface of a line of cleavage between the peroneous longus muscle and the soleus muscle. Subperiosteal dissection is accomplished by reflection of the peroneal muscles anteriorly As the oblique origin of the muscle fibers from the bone tend to press the periosteal elevator toward the fibula, the stripping should begin distally and progress proximally If dissection is carried from the proximal to the distal end of the incision, the reverse is true Small holes are next drilled through the fibula at the proximal and distal ends of the graft. The bone is then osteotomized by connecting the holes by multiple small bites with bone-biting forceps otherwise the bone may be crushed Or a Gigli saw may be employed An osteotome may split or fracture the graft Subsequently the subperiosteal dissection of the graft is completed. The nutrient artery enters the bone near the middle of the posterior surface, and is usually sufficiently large to require ligation

When the proximal end of the bone must be included in the graft, care should be exercised to avoid damage of the peroneal nerve The nerve should first be exposed at the posteromedial aspect of the lower end of the biceps femoris tendon, and traced downward to where it winds around the neck of the fibula. In this location, the nerve is covered by the origin of the peroneus longus muscle the origin of this muscle is divided the back of the knife blade being toward the nerve. The nerve is then displaced from its normal bed into an anterior position. In the subsequent dissection, the anterior tibial vessels which pass between the neck of the fibula and tibia should be protected from injury by subperiosteal dissection Theoretically when the whole fibula is transplanted it would seem advisable to retain the periosteum. Practically this seems unnecessary

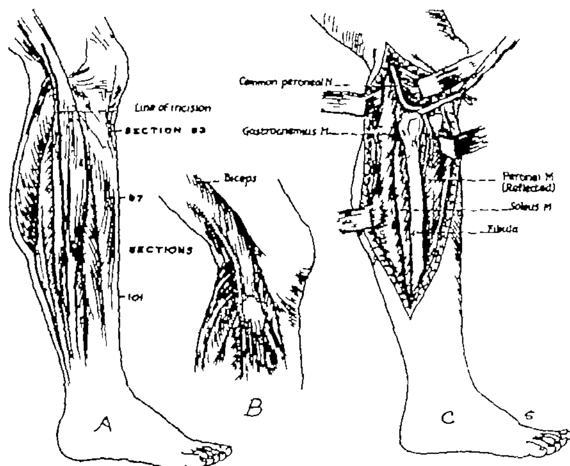


Fig 111 —A Line of incision for removal of fibula levels of cross sections illustrated in Fig 110 are indicated. B Relation of peroneal nerve to head and neck of fibula. C Henry's method of displacing peroneal nerve to expose head and neck of fibula.

Cancellous Grafts —Unless considerable strength is required, the cancellous graft fulfills almost any requirement *Regardless of whether or not* the cells in the graft remain viable clinical results would indicate that cancellous grafts amalgamate with the host bone much more rapidly than the cortical grafts.

If form and rigidity are unnecessary multiple sliver or chip grafts may be removed When preservation of the crest is desirable the outer cortex of the ilium may be removed with a rather substantial portion of cancellous bone.

Fig. 112.—Coronal sections (*A B C D*) from anterior portion of ilium. Accompanying cross sections show width of bone and its cancellous structure. Iliac grafts for fusion of spine are ordinarily removed from posterior third of crest (*E F, G*) (From Abbott, Leroy C. Lectures on Reconstruction Surgery Ann Arbor 1944 J W Edwards, Publisher)

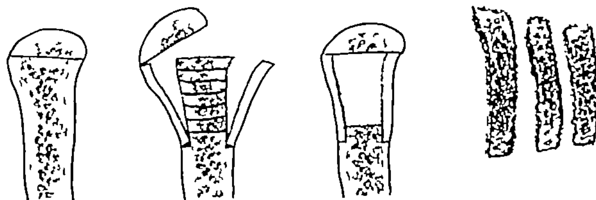


Fig 113—Robertson and Barron method of removing purely cancellous bone chips from ilium.

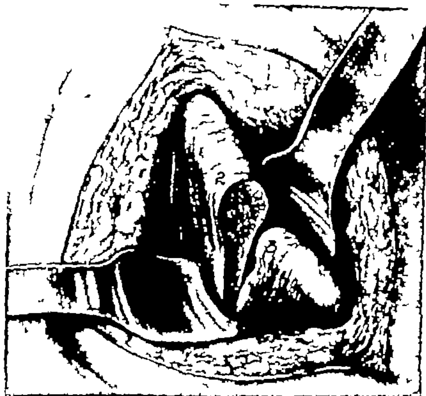


Fig. 114 —Method of removing a full-thickness, coronal segment of ilium. (From Abb Leroy C. Lectures of Reconstruction Surgery Ann Arbor 1944, J W Edwards, Publisher)



Fig 115 —Technic of removing sliver or chip grafts from ilium. Small segments cancellous bone aid in maintaining continuity of grafts. (From Abbott, Leroy C. Lectures Reconstruction Surgery Ann Arbor 1944 J W Edwards, Publisher)

If a more rigid piece of bone is desirable the posterior one-third of the crest of the ilium or the anterior one third of the ilium is a satisfactory donor site For wedge grafts, the cuts are made at a right angle to the crest

If the patient is in a prone position the posterior third of the ilium is utilized If the patient is in a supine position the anterior third of the crest of the ilium is available In children the epiphysis of the iliac crest should be preserved together with the attached muscles To accomplish this, a cut is made parallel to and below the epiphysis and this segment is fractured in a green stick fashion at one extremity After removal of the necessary bone, the fractured crest along with the epiphysis, is replaced in contact with the remnant of the ilium

Exposure of the ilium is relatively simple but may be attended by considerable bleeding An incision is made along the subcutaneous border of the iliac crest, and at the point of contact of the origins of the trunk muscles and the gluteus muscles with the periosteum the incision is carried down to the bone To avoid hemorrhage all subsequent dissection should be subperiosteal If a unicortical cancellous graft is desired only the muscles on the outer table of the ilium are elevated. For bicortical or full thickness grafts the iliac muscle must be stripped from the inner table of the ilium Chip or sliver grafts are removed with an osteotome parallel to the crest of the ilium After removal of the crest a considerable quantity of cancellous bone may be obtained by the insertion of a curette into the cancellous space between the two intact cortices.

In removing an outer table cortical graft, the area is first outlined with an osteotome. The graft may then be peeled up by slight prying motions with a broad osteotome

The removal of wedge grafts or full thickness grafts may be facilitated by the use of a motor saw further this technic produces considerably less trauma For this purpose, the reciprocating unit of a Luck saw is quite satisfactory

After removal of the grafts the periosteum together with muscular origins should be accurately apposed and sutured by interrupted stitches of chromic catgut We ordinarily try to preserve the origin of the rectus femoris and the sartorius muscles although no deleterious effects will necessarily follow if they are reattached at a lower level to the adjacent soft tissues or to a lower location on the ilium

PNEUMOROENTGENOGRAPHY

The usefulness of pneumoroentgenography is limited chiefly to the knee joint, and especially to cases wherein there is some question as to internal derangement and the ordinary roentgenograms are negative Bonnin and Boldero have experimented at length with pneumoroentgenography in normal and pathologic knees and have compared their roentgenographic findings with the surgical findings. They definitely feel that the procedure is of value when clinical evidence is inconclusive, when posterior horn or double lesions are suspected, or if there is a question as to whether an unstable knee or ruptured cartilage is responsible for the symptoms.

Technic (Bonnin and Boldero) —The knee joint is emptied of all effusion and is filled with air preferably with a needle of relatively small caliber

Cole W H. The Treatment of Claw Foot, J Bone & Joint Surg 22 895 1940
Dick, I. L. Iliac Bone Transplantation Preliminary Observations J Bone & Joint Surg 28 1 1946.
Eggers, G W N: Internal Contact Splint J Bone & Joint Surg 30-A 40 1948.
Freiberg A H The Removal of the Meniscus From the Knee Joint J Bone & Joint Surg 3 69, 1921
Ghormley R. K.: Choice of Bone Graft Methods in Bone and Joint Surgery, Ann. Surg 115 427, 1942.
Hart Deryl Sterilization of the Air in Operating Rooms With Bactericidal Radiation, J Thoracic Surg 7 525 1938
Henderson, M. S. Nonunion in Fractures; The Massive Bone Graft J A M. A. 81 463 1923
Henry M. O: Homografts in Orthopedic Surgery J Bone & Joint Surg 30-A 70 1948
Inclan, A.: The Use of Preserved Bone Graft in Orthopedic Surgery, J Bone & Joint Surg 24 81 1942.
Key J A.: Electrolytic Absorption of Bone Due to the Use of Stainless Steels of Different Composition for Internal Fixation Surg Gynec. & Obst. 82 319, 1946.
Key, J A. Fixation of Tendons, Ligaments and Bone by Bunnell s Pull-Out Wire Suture, Ann. Surg 123: 656, 1946.
Kleinberg Samuel Pneumarthrosis as a Diagnostic Aid. Report of a Case of Loose Internal Semilunar Cartilage Arch. Surg 8 827 1924
Lewin, Philip: Instruments for Making Curved Holes in Certain Bones, J Bone & Joint Surg 11 59, 1929
Lowe, Frank A., and Breck, Louis W: A New Knife for Use in Removing Semilunar Cartilages, J Bone & Joint Surg 20 220 1938
Luckey C. A., and Adams, C. O: The Use of Iliac Bone in Bone-Grafting and Arthrodesis, J Bone & Joint Surg. 28 521 1946.
Maes, Urban Aseptic Surgical Technic, Practice of Surgery Dean Lewis Hagerstown, 1937, W F Prior Co., Inc., Vol. I, Chap. VII.
Mitchell, Joe L. A Rotary Bone File J Bone & Joint Surg 13 598 1931
Murray, C R.: The Principles Underlying All Bone Grafting Procedure, Am. Acad. Orthop Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944 J W Edwards.
Orell, Svante Studies of Bone Implantation New Bone Formation, Implantation of "Os Purum, and Transplantation of Os Novum, Acta chir Scandinav (Supp. 31) 74 1 1934
— Surgical Bone Grafting With Os Purum, Os Novum, and Boiled Bone,' J Bone & Joint Surg 19 873 1937
Orsos, E. (Action Currents Induced by Metal Fixation of Bone), 27th Report of Progress in Orth. Surg., p. 28 (Abstracted from Zentralbl. f. Chir 52 1014 1925)
Peterson, L. T: Fixation of Bones by Plates and Screws, J Bone & Joint Surg 29 335, 1947
Quaintance, Paul A. Pneumoroentgenography of the Knee Joint J Bone & Joint Surg 20 353 1938.
Reid, Mont R., and Stevenson, Jean The Treatment of Fresh Wounds Surg Gynec. Obst. 66 318, 1938 Internat. Abst. Surg
Riedel Gustav Haltelochplatte für Schanz sche Schrauben (Fixation Perforation Plate for Schanz Screws) Zentralbl. f Chir 57 84 1930
Robertson, Ivor M., and Barron, J N A Method of Treatment of Chronic Infective Osteitis, J Bone & Joint Surg 28 19, 1946.
Siegling John A., and Fahey, John J The Fate of the Transplanted Cow s Horn J Bone & Joint Surg 18 430 1936.
Steindler Arthur: A Textbook of Operative Orthopedics, New York, 1925 D Appleton Co., pp 1 8.
Street, D M., Hansen H. H., and Brewster B J The Medullary Nail Presentation of a New Type, Arch. Surg 55 423, 1947
Townsend K., and Gilfillan, C: A New Type of Bone Plate and Screws, Surg. Gynec. Obst. 77 595 1943
Venable Charles S. Osteosynthesis in the Presence of Metals Studies on Electrolysi South M J 31 501, 1938.
Venable, C. S., and Stuck, W G: The Internal Fixation of Fractures, Springfield, Ill., 1947 Charles C Thomas, Publishers.
Venable, Charles S., Stuck, Walter G., and Beach Asa: The Effects on Bone of the Presence of Metals Based Upon Electrolysis an Experimental Study Ann. Surg 105 917, 1937

CHAPTER IV

SURGICAL APPROACHES

The determination of priority for a given surgical approach is often difficult, largely because of the fact that the majority of incisions in popular use are variations of incisions which were originated long ago. In this chapter, the more recent modifications of approaches to the bones and joints will be described and, in so far as possible proper credit will be given their originators. The surgical approaches to the joints, beginning below with the foot and continuing upward, will receive first consideration.

THE JOINTS

TOES

Approaches to the Interphalangeal Joints

Technic.—For operations upon the interphalangeal joint of the great toe, an incision one inch long should be made on the medial aspect of the toe. For access to the joints of the fifth toe, a lateral incision is made. The second, third, and fourth toes may be approached through an incision just lateral to the corresponding extensor tendon. Dissection is carried through the subcutaneous tissue and fascia to the capsule of the joint. The edges of the incision are reflected, with care to avoid damage to the dorsal or plantar digital vessels and nerves the former are retracted upward and the latter downward. The capsule is opened transversely or longitudinally, exposing the articular surfaces.

Approaches to the Metatarsophalangeal Joint of the Great Toe

The metatarsophalangeal joint of the first toe may be exposed by several procedures.

Medial Approach

Technic.—A curved incision two inches in length is made on the medial aspect of the joint beginning just proximal to the interphalangeal articulation, curving upward over the dorsum of the first metatarsophalangeal joint internal to the extensor hallucis longus tendon, and terminating on the medial aspect of the first metatarsal bone one inch proximal to the metatarsophalangeal joint. As the deep fascia is incised, the medial branch of the first dorsal metatarsal artery should be retracted laterally. The fascia is dissected from the dorsum down to the bursa over the medial aspect of the head of the first metatarsal bone. A curved incision is then made through the bursa and capsule of the first metatarsophalangeal joint, beginning over the dorsomedial aspect of the joint and continuing proximally dorsal to the head of the first metatarsal bone, thence downward and forward around the joint, ending distally on the medioplantar aspect of the metatarsophalangeal joint. Thus, an elliptical racquet shaped flap attached at the base of the proximal phalanx, is formed. By reflection of this flap distally the first metatarsophalangeal joint is amply exposed. Since healing of the skin flap may be delayed the dorsomedial approach is better

Dorsomedial Approach

Technic.—The dorsomedial approach is begun just proximal to the inter phalangeal joint and continued for a distance of two inches parallel with and medial to the extensor hallucis longus tendon The fascia is divided and the tendon retracted, exposing the capsule and periosteum The capsule may be incised to form a flap with its attachment at the base of the first phalanx as in the preceding approach or the joint may be exposed by continuing the dissection in the plane of the skin incision

Dorsolateral Approach

McBride uses the dorsolateral approach in operations for hallux valgus (Chapter XXIV)

Technic.—The dorsolateral incision begins at the level of the inter phalangeal joint of the great toe and extends proximally three inches through the fascia along the lateral margin of the extensor hallucis longus tendon. Retraction of this tendon brings into view the lateral and dorsal aspects of the capsule of the first metatarsophalangeal joint the capsule is incised transversely on these surfaces. The joint may now be dislocated by medial and plantar traction on the great toe thus providing exposure of the entire joint for operations on the head of the metatarsal bone the base of the first phalanx, or the adductor hallucis tendon.

Approaches to the Metatarsophalangeal Joints of the Second, Third, Fourth, and Fifth Toes

The second third and fourth metatarsophalangeal joints are reached by a lateral longitudinal incision parallel to and below the corresponding extensor tendon. The joint capsules may be opened transversely or longitudinally as necessary Exposure of the fifth metatarsophalangeal joint is best accomplished by a straight or curved dorsal or dorsolateral incision

TARSUS AND ANKLE

Anterolateral Approach

Exposure of the tarsal and ankle joints can best be accomplished by the anterolateral incision This procedure gives excellent access to the ankle joint, the astragalus, and other tarsal bones and joints, and is by far the most useful approach to this region. Further all important vessels and nerves are avoided.

Technic.—Beginning over the anterolateral aspect of the leg medial to the fibula and two inches proximal to the ankle joint, the incision is carried distally over the joint the anterolateral aspect of the body of the astragalus and the calcaneocuboid joint terminating at the base of the fourth metatarsal bone The incision may begin higher and terminate lower or any part may be used according to the requirements of the case The fascia and transverse crural and cruciate crural ligaments are incised down to the periosteum of the tibia and capsule of the ankle joint the anterior lateral malleolar and lateral tarsal arteries usually are divided by this dissection The extensor digitorum brevis muscle is then divided in the direction of its fibers or detached from its origin

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and reflected distally The extensor tendons are retracted medially with the dorsalis pedis artery and deep peroneal nerve and the capsule is incised revealing the ankle joint. The articulation of the astragaloscaphoid joint is next exposed by dissection deep to the tendons, and the capsule is incised transversely *Dissection is then continued laterally through the capsule of the calcaneocuboid joint, which lies on the same plane as the astragaloscaphoid joint.* A mass of fat lateral to and below the neck of the astragalus is incised bringing the subastragalar joint into view Access to the articulation between the cuboid bone and the fourth and fifth metatarsal bones, and between the scaphoid and third cuneiform bones may be obtained by prolongation of the dissection distally

Since so many reconstruction operations and other procedures involve the structures exposed this approach may well be called the "universal *incision" for the foot and ankle. By this procedure, the entire astragalus* may be excised and the only tarsal joints which cannot be reached are those between the scaphoid and the second and first cuneiform bones.

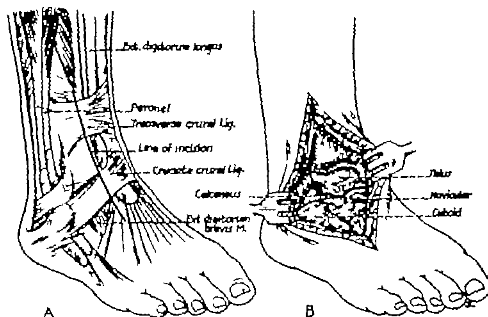


Fig 117.—Anterolateral incision for exposure of ankle joint and tarsus.

Kocher Approach

This approach gives excellent exposure of the midtarsal, subastragalar and ankle joints.

Technic.—From a point just lateral and distal to the head of the astragalus, the incision is carried in a curved direction one inch below the tip of the external malleolus then backward and upward terminating one inch posterior to the fibula and two inches proximal to the tip of the external malleolus. If desired, the incision may be extended upward two or three inches parallel with and posterior to the fibula. The fascia is incised to the peroneal tendons and these structures are retracted posteriorly If an extensive operative field is necessary, the tendons may be divided in a z-plastic manner and retracted. Dissection is then continued downward and the external lateral ligament is severed at the ankle joint, exposing the subastragalar articulation The calcaneocuboid articulation may be reached through the distal portion of this incision on the same

plane with the astragaloscaphoid articulation Dislocation of the ankle by medial traction affords access to the entire articular surface

The disadvantage of this procedure lies in the fact that there is often sloughing of the skin about the margins of the incision especially if dislocation of the ankle is necessary as in astragalectomy Further, the peroneal tendons must usually be divided In the majority of cases, the anterolateral incision is far more satisfactory

Ollier Approach

Technic.—The skin incision begins over the dorsolateral aspect of the talonavicular joint and extends obliquely downward and backward terminating approximately one inch below the external malleolus. The cruciate crural ligament is divided in the line of the skin incision The long extensor tendons to the toes are exposed in the upper portion of the incision and retracted medially, preferably without opening the tendon sheath. The peroneal tendons are exposed in the lower portion of the incision and retracted downward. The origin of the extensor digitorum brevis muscle is divided and the muscle retracted distally bringing into view the sinus tarsi From this point the dissection is extended to expose the subtalar calcaneocuboid and talonavicular joints.

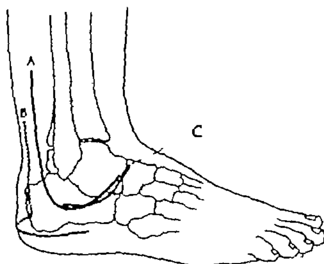


Fig 113.—*A* Kocher approach to ankle *B* Kocher approach to os calcis. *C* Ollier approach to midtarsal and subtalar joints

This is an excellent approach for a triple arthrodesis the three joints are exposed through a relatively small opening, without excessive retraction and the wound usually heals well.

Posterior Approach

Technic.—An incision five inches in length is made along the posterolateral border of the tendo achillis, down to the insertion of the tendon into the os calcis. The superficial and deep fasciae are divided the tendo achillis is lengthened by the Z-plastic method or retracted and the fat and areolar tissue are incised to the posterior surface of the tibia in the interval between the flexor hallucis longus and the peroneal tendons. By retraction of the flexor hallucis longus tendon medially one inch of the lower end of the tibia, the

posterior aspect of the ankle joint, the posterior extremity of the astragalus, the subastragalar joint, and the *posterior portion of the superior surface of the os calcis* may be exposed. If one is careful to carry the dissection lateral to the flexor hallucis longus tendon the posterior tibial artery and nerve will not be damaged since they are protected by this tendon.

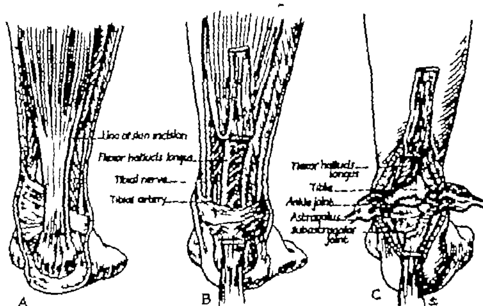


Fig. 118.—Posterior approach to ankle. *A*, Line of skin incision. *B* Z-plastic division and reflection of tendo achillis. *C* Exposure of ankle and subastragalar joints after retraction of flexor hallucis longus tendon and posterior capsulotomy

Medial Approach

Koenig and Schaefer have approached the ankle on the inner aspect by a method similar in principle to the Kocher exposure of the outer side This is not a popular method as injury to the tibial vessels and nerve is possible *despite constant vigilance*

Technic.—The incision curves around the internal malleolus, and the malleolus is divided with an osteotome the attachment of the deltoid ligament being preserved. The talus is then subluxated outward with the malleolus, *giving access to the joint surfaces* The malleolus is later replaced and fixed with a screw

This method may be useful for fracture-dislocations of the talus and other traumatic lesions of the ankle joint

In addition to the incisions described above, short internal, lateral, and dorsal incisions may be employed to expose limited areas of the tarsal and metatarsal joints. In all the vessels, tendons, and nerves should be protected from injury

KNEE*

Anteromedial Approach

The anteromedial approach was originally described by Langenbeck

Technic.—The anteromedial incision begins on the medial border of the quadriceps tendon, three or four inches above the knee joint, and extends distally to one-half inch above the patella, thence curves medially around the

* For an exhaustive review of approaches to the knee joint, the reader is referred to an article by Abbott and Carpenter

inner border of the patella and returns toward the midline, terminating at or below the tibial tubercle The fascia is divided and retracted Dissection is now carried between the vastus internus muscle and the medial border of the quadriceps tendon and the capsule and synovial membrane are incised along the medial border of this tendon and the patella and patellar tendon The patella is retracted laterally and the knee flexed giving a good view of the anterior compartment and superior culdesac When radical surgery is to be undertaken, severance of the crucial ligaments will provide access to the entire joint. If contracture of the quadriceps prevents adequate exposure, the tibial tubercle may be detached and after completion of the operation, reattached and fixed by the insertion of a steel nail or Vitallium screw

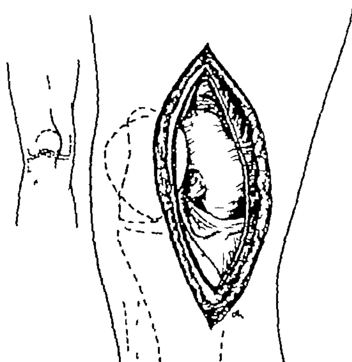


Fig 120.—Anteromedial approach to the knee joint.

Anterolateral Approach

Technic (Kocher) —The incision begins three inches above the patella at the insertion of the vastus externus muscle into the quadriceps tendon and is continued downward along the lateral border of the quadriceps, the patella and patellar tendon, terminating one inch below the tibial tubercle. Dissection is extended downward through the joint capsule The patella, with the attached tendons above and below is retracted medially bringing into view the articular surface

The above procedure is less satisfactory than the anteromedial approach

Anterior Approach

Technic (Coonse and Adams) —A longitudinal parapatellar incision is made as indicated in the insert Fig 121 the anterior surfaces of the quadriceps tendon patella, and patellar tendons are exposed. The quadriceps tendon is incised longitudinally in its center from its musculotendinous junction downward to a point approximately one half inch above the upper margin of the

patella. From this point, the approach swings both medial and lateral to the patella dividing the expansion of the quadriceps tendon together with the capsule of the joint Below the patella, the approach is extended downward through the capsule of the joint on both sides of the patellar tendon, to the level of the articular surface of the tibia The synovial membrane is divided parallel with the lines of the capsular incision The patella, together with the patellar tendon, is reflected distally and the knee is flexed to 90 degrees, thus exposing the lower end of the shaft of the femur and the major portion of the knee joint (Fig 121*B*) The medial or lateral condyle of the femur is exposed by retraction. In closing the wound, the patellar flap is restored to its normal position and the quadriceps tendon and capsule of the knee joint are closed with interrupted sutures.

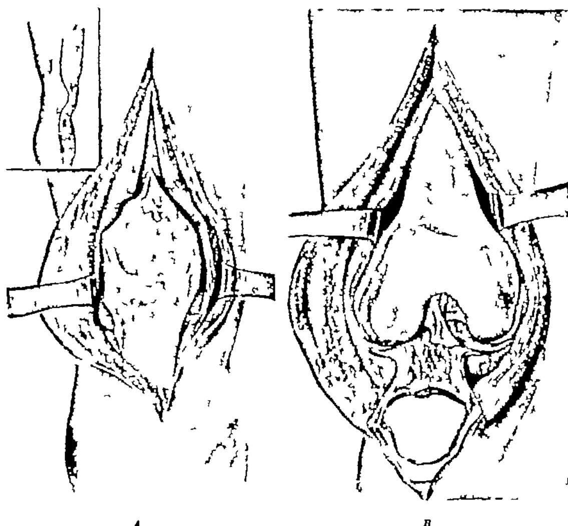


Fig. 121.—Anterior approach to knee joint (Coonse and Adams) *A* Patella and patellar tendon released by inverted Y-incision. Insert shows line of skin incision. *B* Exposure completed, with distal reflection of patella and patellar tendon. (From Coonse, K. D., and Adams, J D. Surg Gynec. & Obst. 77 344 1943.)

In this approach, the division of the quadriceps tendon is a disadvantage however a considerable portion of the expansion of the quadriceps tendon on each side of the patella is left intact. This is an excellent approach for arthrodesis of the knee, since interruption of the quadriceps tendon is not a disadvantage It is also suitable for fractures of the lower end of the femur

involving the knee joint, being sufficiently extensive to allow accurate replacement of the fragments and visualization of the articular surface.

"U" Approach

Technic (Kocher).—The "U" incision of Kocher begins just medial to the quadriceps tendon one-half inch above its insertion into the patella, passes downward medial to the patella and patellar tendon to the level of the tibial tubercle, thence curves over the tibial tubercle and continues upward along the outer border of the patellar tendon and patella ending lateral to the quadriceps tendon opposite the point of its beginning The fascia and capsule are divided throughout the extent of the incision. The tibial tubercle, with the insertion of the patellar tendon, is severed with an osteotome, and the entire flap is reflected proximally thus exposing the joint.

This incision affords an excellent field for excision in the knee joint, but has been discarded in favor of the anteromedial approach

Inverted "U" Approach

Technic.—The inverted "U" incision which is the reverse of the Kocher "U" incision, begins on the medial aspect of the inner condyle of the tibia anterior to the tibial collateral ligament, is carried proximally to a point one inch above the patella, then curved laterally across the quadriceps tendon and continued distally along the anterior border of the fibular collateral ligament to end over the lateral condyle of the tibia. The fascia, capsule, and synovial membrane are incised into the joint. The quadriceps tendon is severed proximal to the patella, or by a Z-plastic incision in the latter event, the lateral portion of the tendon is allowed to remain attached to the patella. The flap is retracted distally

If the quadriceps tendon is to be lengthened, this may be facilitated by a longitudinal incision over the quadriceps tendon extending upward from the apex of the U Putti formerly employed such an approach, but discontinued its use, since occasionally the skin margins were found to slough at the juncture of the longitudinal limb with the U

Split Patella Approach

Technic (Jones and Brackett).—This incision begins two or three inches above the patella and passes downward in the median line to terminate one inch below the tibial tubercle The quadriceps tendon patella and patellar tendon are exposed and divided in the same plane, a small saw being used to split the patella

This approach provides an ample operative field especially in the medial portion of the joint The division of the patella is an undesirable feature particularly in patients beyond middle age as some irregularity of the joint may persist leading to traumatic arthrosis. We therefore prefer the anteromedial incision which affords satisfactory exposure without division of the patella This technic however has been adapted to patellectomy

Posterolateral and Posteromedial Approaches

The posterior compartment of the knee joint may be divided by a mesial septum into internal posterior and external posterior compartments The

patella. From this point, the approach swings both medial and lateral to the patella dividing the expansion of the quadriceps tendon together with the capsule of the joint. Below the patella the approach is extended downward through the capsule of the joint on both sides of the patellar tendon to the level of the articular surface of the tibia The synovial membrane is divided parallel with the lines of the capsular incision The patella, together with the patellar tendon, is reflected distally and the knee is flexed to 90 degrees, thus exposing the lower end of the shaft of the femur and the major portion of the knee joint (Fig 121*B*) The medial or lateral condyle of the femur is exposed by retraction. In closing the wound, the patellar flap is restored to its normal position, and the quadriceps tendon and capsule of the knee joint are closed with interrupted sutures.

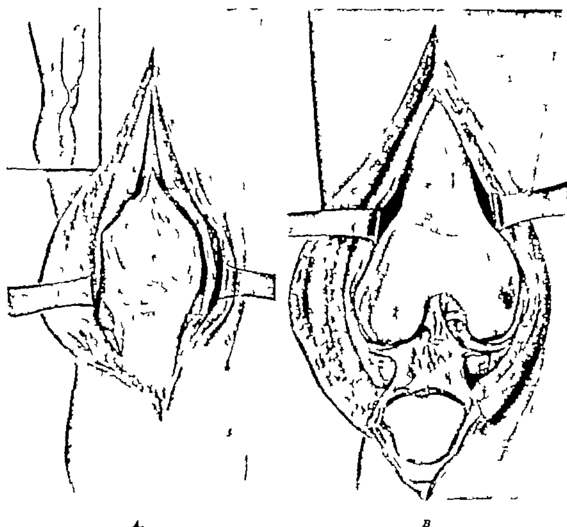


Fig. 121.—Anterior approach to knee joint (Coonse and Adams) *A* Patella and patellar tendon released by inverted Y incision. Insert shows line of skin incision. *B* Exposure completed, with distal reflection of patella and patellar tendon. (From Coonse, K. D and Adams, J D. Surg., Gynec. & Obst. 77 344, 1943.)

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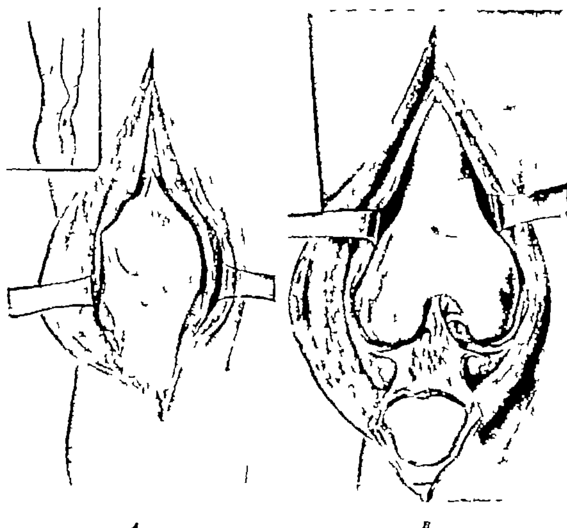


Fig. 121 — Anterior approach to knee joint (Coonse and Adams) *A* Patella and patellar tendon released by inverted Y incision. Insert shows line of skin incision. *B* Exposure completed, with distal reflection of patella and patellar tendon. (From Coonse, K. D., and Adams, J. D. Surg Gynec. & Obst. 77 344, 1943.)

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Fisher Anterior Approach

This incision may be used as an alternative to the Jones incision for removal of the semilunar cartilage

Technic.—Beginning over the internal condyle of the femur at a point level with the upper border of the patella and just anterior to the femoral insertion of the internal lateral ligament the incision is curved downward and laterally and terminated just medial to the patellar tendon one inch below the patella (See Fig 198 *B*)

Approaches to the Anterior and Posterior Compartments

Rarely the following incisions are employed for removal of the entire semilunar cartilage Usually an anterior incision as described by Jones or Fisher is large enough for excision of the anterior two-thirds of the cartilage If, after exposure of the anterior compartment, excision of the entire cartilage seems warranted, a separate Henderson incision will provide exposure of the posterior compartment.

Fisher U Approach

Technic.—The ' U skin incision is begun at a point midway between the ligamentum patellae and the anterior border of the internal lateral ligament at the level of the midpoint of the patella curved backward across the tibia just below the level of the joint and continued upward over the inner aspect

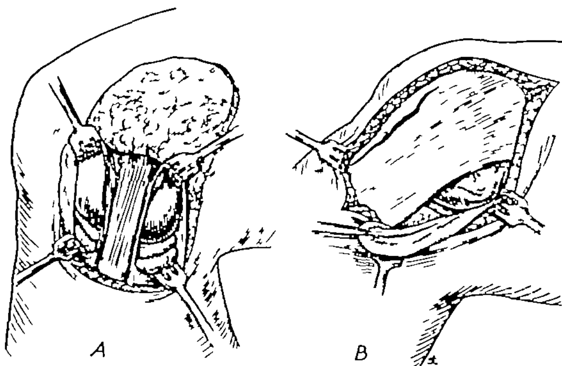


Fig. 123 —Incisions for exposure of anterior and posterior compartments of knee. *A* Fisher U flap incision. *B* Bosworth incision.

of the posterior compartment of the joint. This flap of skin is reflected proximally exposing the internal lateral ligament, the integrity of the ligament is not disturbed Two curved incisions are then made through the capsule and the synovial membrane, one anterior to the ligament and the other posterior to the ligament

posterolateral approach to the external compartment, described by Henderson, may be duplicated for access to the internal compartment. The incision is small and little dissection is needed.

Technic (Henderson).—The knee is flexed and an incision is made on the outer side, just anterior to the tendon of the biceps muscle and the head of the fibula. The common peroneal nerve which passes over the lateral aspect of the head of the fibula, is thus avoided. For exploration of the medial compartment, a second incision may be made on the inner side, anterior to the relaxed tendons of the semimembranosis, semitendinosus, sartorius, and gracilis muscles. The capsule is incised longitudinally revealing the posterior compartment.

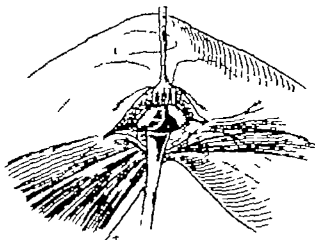


Fig 122.—Henderson posteromedial approach to knee joint.

Posterior Approach

The posterior approach involves anatomic structures which if damaged, may produce a permanent, serious disability. A thorough familiarity with the anatomy of the popliteal space is a prerequisite to the use of this approach.

Technic (Brackett and Osgood, and Putti).—If more extensive exposure is required an S-shaped incision four to six inches in length is made in the center of the popliteal space, exposing the tibial nerve. By retraction of the wound margins, the two heads of the gastrocnemius muscle may be seen in the upper portion of the wound; these are separated bringing the vessels into view. While retracting the lateral head of the gastrocnemius, care should be taken to avoid damage to the common peroneal nerve, which branches from the sciatic nerve in the upper portion of the incision and parallels the biceps femoris tendon. Several motor branches are also given off from the tibial nerve in the region of the incision. Since the majority of these are on the lateral side, the nerve should be retracted laterally; in so doing however the branch which supplies the medial head of the gastrocnemius must be protected from injury. The popliteal artery and vein are likewise retracted laterally. The capsule is then exposed by blunt dissection and incised. If a more extensive field is required, the origins of the heads of the gastrocnemius may be stripped subperiosteally from the bone.

Jones Approach

(See Excision of Internal Semilunar Cartilage Fig 198.)

Fisher Anterior Approach

This incision may be used as an alternative to the Jones incision for removal of the semilunar cartilage

Technic.—Beginning over the internal condyle of the femur at a point level with the upper border of the patella and just anterior to the femoral insertion of the internal lateral ligament, the incision is curved downward and laterally and terminated just medial to the patellar tendon one inch below the patella (See Fig 198 *B*)

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Rarely the following incisions are employed for removal of the entire *semilunar cartilage* Usually *an anterior incision as described by Jones or* Fisher is large enough for excision of the anterior two-thirds of the cartilage If, after exposure of the anterior compartment, excision of the entire cartilage seems warranted a separate Henderson incision will provide exposure of the posterior compartment.

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Technic.—The "U" skin incision is begun at a point midway between the ligamentum patellae and the anterior border of the internal lateral ligament, at the level of the midpoint of the patella, curved backward across the tibia just below the level of the joint, and continued upward over the inner aspect

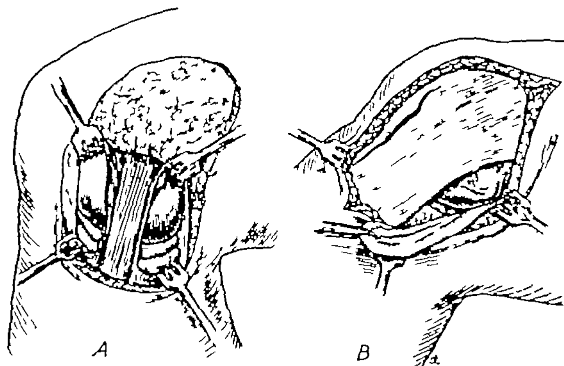


Fig. 121.—Incisions for exposure of anterior and posterior compartments of knee. *A* Fisher U flap incision. *B* Bosworth incision.

of the posterior compartment of the joint. This flap of skin is reflected proximally exposing the internal lateral ligament the integrity of the ligament is not disturbed Two curved incisions are then made through the capsule and the synovial membrane, one anterior to the ligament and the other posterior to the ligament.

Cave Approach

This is a curved incision which allows complete exposure of both the anterior and posterior compartments Bosworth has recently described a similar exposure.

Technic.—With the knee flexed to a right angle, the internal epicondyle of the femur is identified and the incision begun three-eighths inch behind and on a level with this point, approximately one-half inch above the joint line. The incision is carried distally and anteriorly to a point one fourth inch below the joint line, thence forward to the border of the patellar tendon. After reflection of the subcutaneous tissues, the anterior compartment is exposed through an incision which begins in front of the lateral ligament, continues downward and forward in a curve similar to that of the skin incision, and ends just below the joint line. (See Fig 199)

For exposure of the posterior compartment a second subcutaneous incision is made posterior to the internal lateral ligament, from the level of the epicondyle of the femur straight downward across the joint line

HIP

Anterior Iliofemoral Approach

To Smith Petersen must be given the credit for improving and reviving interest in the anterior iliofemoral incision previously described by Bardenheuer Sprengel, and Larghi. Through his efforts, this has become the most popular approach to the hip joint.

Technic (Smith Petersen)—Beginning at the middle of the crest of the ilium, the incision passes forward to the anterior superior iliac spine, thence distally and slightly laterally four or five inches For a larger exposure, the incision may begin as far posteriorly on the crest of the ilium as desired. The superficial and deep fasciae are divided and the attachments of the gluteus medius and the tensor fasciae femoris muscles are severed from the iliac crest. By means of a periosteal elevator the periosteum, with the attachment of the gluteus medius and minimus muscles, is stripped from the external surface of the ilium. Packing of the interval between the ilium and the reflected muscles will control bleeding from the nutrient vessels. Dissection is now carried through the deep fascia of the thigh, and between the tensor fasciae femoris laterally and the sartorius and rectus femoris medially The ascending branch of the lateral femoral circumflex artery which is encountered two inches below the hip joint, should be clamped and ligated. One inch below the anterior superior spine, the lateral femoral cutaneous nerve will be observed as it passes over the sartorius this should be retracted to the medial side If the structures at the anterior superior spine are contracted the spine may be freed with an osteotome and permitted to retract, with its muscular attachments, to a lower level. The iliofemoral ligament (or Y ligament of Bigelow) on the anterior portion of the capsule should be preserved. The capsule is exposed and incised transversely revealing the head of the femur and upper margin of the acetabulum With a curved knife or scissors, the ligamentum teres may be severed and the head of the femur dislocated giving access to all parts of the joint.

Practically all surgery of the hip joint may be carried out through this anterolateral incision, separate portions being employed for different purposes. For example, the anterior femoral incision or that of Hueter, is the femoral portion of the incision this exposes the joint but is inadequate for reconstructive measures. The entire ilium and hip joint may be reached through the iliac portion all structures attached to the iliac crest from the posterior superior iliac spine to the anterior superior iliac spine are severed and are reflected from the external surface of the ilium, dissection is carried downward to the anterior inferior iliac spine

Smith Petersen has modified and improved this approach for extensive surgery of the hip joint by reflecting the iliacus muscle from the medial surface of the anterior portion of the ilium, and by detaching the rectus femoris muscle from its origin These additions are especially valuable in performing an arthroplasty of the hip (Chapter XVII)

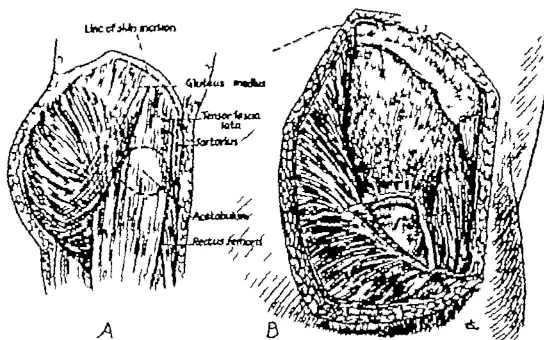


Fig. 124—Anterior iliofemoral approach to hip. *A* Line of skin incision. *B* Exposure of joint after reflection of tensor fasciae femoris and gluteal muscles from lateral surface of ilium, and division of capsule.

Lateral U Approach

Technic.—Beginning at the anterior superior spine, the incision passes distally below the greater femoral trochanter across the femur, thence proximally and posteriorly terminating midway between the femoral trochanter and posterior superior spine of the ilium Dissection is carried through the fascia then between the gluteus medius muscle posteriorly and the tensor fasciae femoris anteriorly down to the greater trochanter With an osteotome, the latter is removed in toto and reflected proximally with the attached pyriformis, obturator gemelli and gluteal muscles. Dissection is next extended posteriorly separating the fibers of the gluteus maximus muscle throughout the extent of the skin incision The entire flap is retracted proximally and the capsule is incised longitudinally along the superior surface of the neck of the femur exposing the neck and hip joint. Care must be taken

to protect the capsular branch of the medial femoral circumflex artery which enters the neck of the femur by way of the posterior portion of the capsule and supplies the head and neck of the femur. The importance of this vessel has been demonstrated by Wolcott. In closure the trochanter is re-attached by sutures, screws, or nails.

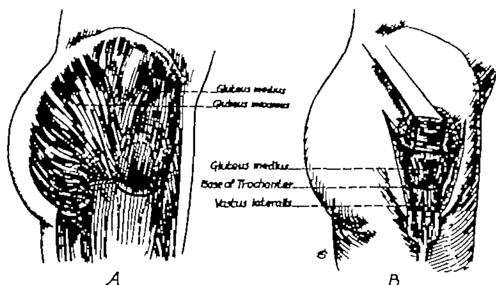


Fig. 125.—Lateral U-approach to hip. A Relation of skin incision to deep structures. B After reflection of skin flap.

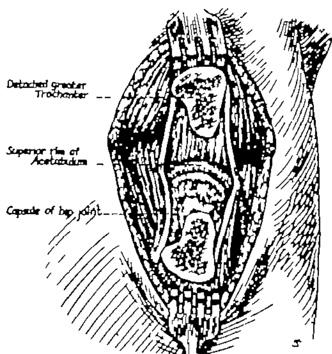


Fig. 126.—Same approach as in Fig. 125. Greater trochanter divided and reflected proximally, with its muscular attachments, capsule incised anteriorly and posteriorly exposing superior surface of neck of femur and hip joint.

This approach was advocated by Murphy and others. Murphy however added to the center of the U a vertical incision, making the entire approach goblet-shaped and thus providing better exposure of the shaft and wide dissection of the soft tissues for plastic procedures, such as arthroplasty

Posterior Approach

Osborne has suggested an approach which combines the features of the posterior incisions of Kocher and Langenbeck

Technic (Osborne) —The incision begins one and three-fourths inches below and lateral to the posterior superior iliac spine, passes laterally and distally parallel with the fibers of the gluteus maximus muscle to the posterior superior angle of the greater trochanter thence down the posterior border of the trochanter for two inches. The fibers of the gluteus maximus muscle are separated parallel with the line of incision The insertion of the gluteus maximus into the fascia lata is divided for a distance of two inches, corresponding to the vertical limb of the incision The thigh is rotated internally the tendons of the pyriformis and gemelli muscles are detached close to their insertions into the trochanter and the muscles are retracted medially The gemelli protect the sciatic nerve The capsule of the joint is now within view and may be incised longitudinally to expose the posterior surface of the femoral neck and posterior border of the acetabulum Further exposure may be obtained by retraction of the gluteus medius muscle upward and of the quadratus femoris muscle downward The upper limb of this incision is similar to that described by Ober

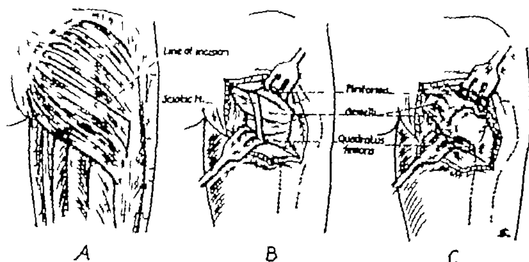


Fig. 127—Posterior approach to hip A Line of skin incision. B, Gluteus maximus muscle divided and retracted, revealing structures deep to this muscle. C, Pyriformis, gemelli, and obturator internus muscles divided at insertions and reflected medially revealing posterior aspect of neck of femur and hip joint.

These approaches are excellent for drainage of infections about the hip joint for fracture-dislocations of the hip (Fig 223) and may be used occasionally for providing access to tumors along the posterior surface of the neck of the femur In elective procedures about the hip the anterior incisions are superior

Lateral Approach

Technic (Callahan).—The skin incision begins just distal to the anterosuperior spine and extends downward toward the knee to a point approximately one-third the distance from the spine to the knee thence curves posteriorly in hockey-stick fashion (Fig 128A) The interval between the anterior border of the tensor fascia femoris muscle and the sartorius is developed and traced

distally to the insertion of the tensor fascia femoris into the fascia lata. The fascia lata is divided transversely in the lower portion of the incision. The tensor fascia femoris and gluteus medius are retracted posteriorly and the rectus femoris is retracted medially. The branches of the lateral circumflex vessels are isolated, clamped and cut. Ligation of these vessels and, as a rule, two or three small branches, provides an almost bloodless approach to the neck of the femur. The iliacus and lateral portion of the rectus muscles are retracted medially bringing into view the capsule of the hip joint. The head and neck of the femur are exposed by incision of the capsule parallel with the neck of the femur from the acetabular rim to the intertrochanteric line. If further exposure of the hip is needed, the capsule may be divided at its attachment to the acetabular rim.

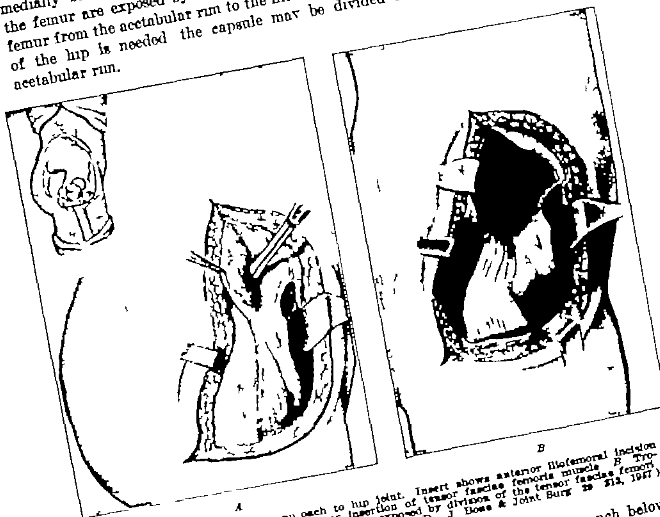


Fig. 128.—*A*, Callahan approach to hip joint. Insert shows anterior iliofemoral incision with distal end curving backward over insertion of tensor fasciae femoris muscle. *B*, Trochanter, upper portion of shaft, and hip joint exposed by division of the tensor fasciae femoris muscle in line with skin incision. (From Wilson, P. D.: J. Bone & Joint Surg. 29: 313, 1947.)

Technic (Watson-Jones).—A curved incision, beginning one inch below and lateral to the anterior superior iliac spine, is carried downward and posteriorly over the lateral aspect of the greater trochanter and lateral surface of the shaft of the femur to two inches below the base of the trochanter. The interval between the gluteus medius and tensor fasciae femoris is located just above the insertion of the gluteus medius, and the dissection continued between these muscles; the former is retracted backward and the latter forward. The capsule of the joint is incised longitudinally along the anterosuperior surface of the neck of the femur. In the lower portion of the incision the vastus

lateralis origin may be reflected downward or split longitudinally to expose the base of the trochanter and upper end of the shaft of the femur

If a wider field is desired the anterior fibers of the tendon of the gluteus medius may be detached from the trochanter, or the anterior superior portion of the greater trochanter may be reflected upward by means of an osteotome together with the insertion of the gluteus medius muscle

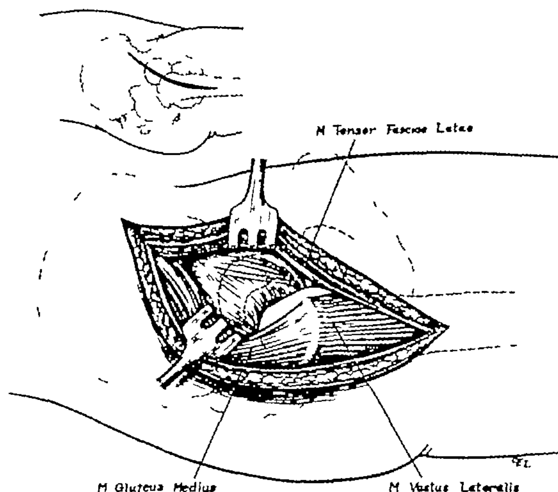


Fig 129—Watson Jones lateral approach to hip joint. Insert shows line of skin incision.

SACROILIAC JOINT

Posterior Approach

Technic.—An incision is made along the outer lip of the posterior third of the crest of the ilium to the posterior superior spine. Dissection is carried down to the iliac crest, the lumbodorsal fascia is separated from the crest and the aponeurosis of the sacrospinalis muscle together with the periosteum is detached and reflected medially, thus exposing the posterior margin of the sacroiliac joint. This exposure is adequate for extra articular fusion. To expose the articular surfaces of the joint for drainage or intra articular arthrodesis, the skin incision is continued distally and laterally two to three inches from the posterior superior spine. The gluteus maximus muscle is split in line with its fibers, or its origin on the crest of the ilium, aponeurosis of the sacrospinalis and sacrum is incised and reflected laterally and distally exposing the posterior portion of the ilium A full thickness segment

of the ilium approximately one-half to three-fourths inch wide, is removed with an osteotome, beginning at the posterior border of the ilium between the posterior superior and inferior spines and extending laterally and slightly upward for one and one-half to two inches. The inferior border of this section roughly parallels the superior border of the greater sciatic notch

SPINE

Approach to the Dorsal Aspect of the Spine

This approach has been recommended by Hibbs and others. Wagoner has recently described the technic in elaborate detail

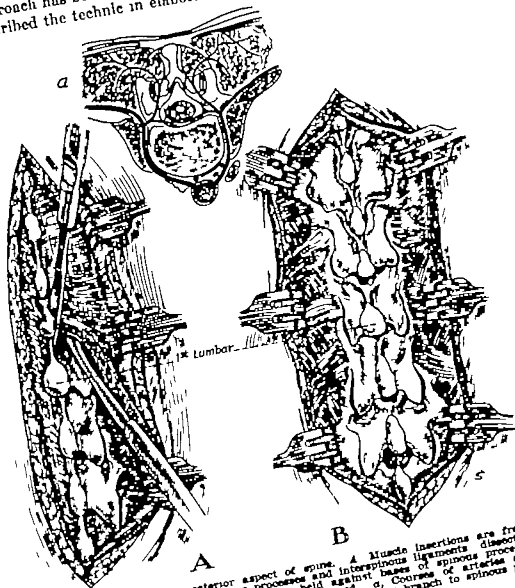


Fig 130 —Approach to posterior aspect of spine. *A* Muscle insertions are freed subperiosteally from lateral side of spinous processes and interspinous ligaments dissection proceeds proximally the periosteal elevator being held against bases of spinous processes. *B* Spinous processes, laminae, and articular facets exposed. *a*, Courses of arteries supplying posterior spinal muscles, showing proximity of internal muscular branch to spinous processes. (From Wagoner George J Bone & Joint Surg. 19 469 1937)

Technic (Wagoner) —A longitudinal incision is made over the spinous processes of the vertebrae in the operative region ordinarily not more than eight vertebrae are exposed at one operation The superficial fascia, the lumbodorsal fascia, and the supraspinous ligaments are incised longitudinally directly over the tips of the spinous processes.

With a scalpel, the ligament between the two spinous processes in the lowermost portion of the wound is divided longitudinally. A small blunt pointed periosteal elevator is placed through this opening so that its point rests on the juncture of the spinous process with the lamina of the upper of the two vertebrae. By rotation of the handle of the elevator upward and laterally the muscles attached to the spinous process are placed under tension. The muscles are then severed subperiosteally from the side of the spinous process, a scalpel being used for this purpose. The elevator is again placed in the wound in such a manner that its point rests on the junction of the spinous process with the lamina of the vertebra above, by rotating the instrument upward and outward the muscles are placed under tension and severed from the lateral surface of the spinous process, as described above. This procedure is repeated until the desired number of vertebrae have been exposed. For operations on both sides of the spine a similar technic is followed on the opposite side.

This incision gives access to the spinous processes and medial portion of the laminae. A wider field may be provided by further subperiosteal reflection along the laminae of the vertebrae. By this process, the dorsal surface of the laminae and the articular facets are brought into view. If each segment is packed with a tape sponge immediately after exposure, hemorrhage will be negligible. The supraspinous ligament must be divided exactly over the tip of the spinous processes, and the sides of the processes must be denuded subperiosteally as this route leads through a relatively avascular field otherwise, one will encounter the arterial supply to the muscles. This fact is illustrated in Wagoner's article from which Fig 130 was taken. Loss of blood from this incision may be further minimized by the use of the electrocautery and a suction apparatus.

The spinous processes should be exposed from below upward since the fibers of the majority of the muscles extend in this direction. The muscles may thus be stripped from the spinous processes in the acute angle between their insertions and the bone. If the reverse method of exposure is attempted, the knife blade will tend to follow the direction of the fibers into the muscle resulting in division of the arteries and hemorrhage.

TEMPOROMANDIBULAR JOINT

Technic.—An incision one and one-fourth inches in length is made along the zygomatic arch to one-fourth inch anterior to the tragus, from this point, the incision may be extended downward one half inch, upward a distance of one-half to one inch (Murphy) or gently curved upward posteriorly over the base of the pinna of the ear (Burdick)

MacAusland has modified the L incision beginning one inch in front of the ear and one half inch above the zygoma curving downward over the joint, and terminating one inch forward on the ramus of the mandible (Fig 777). In developing the deeper portions of these incisions, the facial nerve and the superficial temporal and transverse facial arteries must be avoided. The superficial and deep fasciae are divided to the zygomatic arch along the horizontal limb of the incision. The temporomandibular ligament is incised along its attachment to the zygomatic process and the triangular flap of tissue thus exposed, including a portion of the parotid gland, is reflected downward

and forward, bringing the temporomandibular joint into view. Before exposure of the temporomandibular joint the patient should be forewarned of the possibility of injury to the facial nerves. Following the use of the above incision there is usually temporary and occasional permanent weakness or paralysis of the frontalis muscle, which prevents the patient from wrinkling the forehead. The function of the muscles of the eyelids may also be temporarily impaired. In our experience, however, the only permanent weakness or paralysis which has been noted following this procedure has been limited to the frontalis muscle. Weakness of the frontalis muscle is not distressing; the patient rarely complains of inability to wrinkle the forehead. Care should also be taken to avoid incision of any portion of the parotid gland; damage to the glandular structure may result in a salivary fistula.

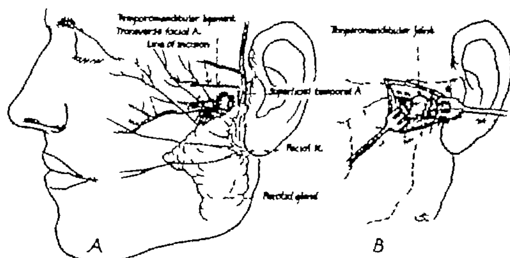


Fig. 131.—A, L-incision for exposure of temporomandibular joint. B, Temporomandibular ligament divided and reflected downward and forward.

STERNOCLAVICULAR JOINT

Technic.—An incision is made along the medial one and one-half inches of the clavicle and extended over the sternoclavicular joint to the midpoint of the sternum. The fascia and periosteum are incised, and the origins of the sternocleidomastoid and pectoralis major muscles are reflected subperiosteally, the former upward, the latter downward, thus exposing the sternoclavicular joint. In extensive operations wherein the under surface of the joint is to be exposed, care must be taken to avoid puncture of the pleura or damage to the internal mammary artery.

SHOULDER

Anteromedial Approach

Technic (James E. Thompson, and Henry).—This incision begins over the anterior portion of the acromioclavicular joint, passes medially along the anterior margin of the outer one-third of the clavicle, then turns downward, following the anterior margin of the deltoid muscle to a point two-thirds the distance between its origin and insertion. Or a curved incision may be made through the skin and subcutaneous tissue, extending over the outer third of the clavicle to the tip of the acromion, then downward to a point one and

one-half inches above the insertion of the deltoid. The latter is preferable as the sharp corner (Fig. 132) may result in moderate necrosis of the skin margin at the apex of the triangular flap. The medial edge of the wound is reflected to expose the anterior margin of the deltoid and its origin from the clavicle. The interval between the deltoid and pectoralis major muscles is located and the medial border of the deltoid is isolated and retracted. The cephalic vein which lies in the interval between the muscles, should be protected during this procedure. The origin of this muscle is then detached from the clavicle either by severance near the bone, by subperiosteal elevation, or by removal of a portion of the bone intact with its deltoid origin. The first is preferred, a sufficient amount of soft tissue being left attached to the clavicle to allow resuture of the reflected deltoid to its point of origin when the wound is closed. The anterior portion of the deltoid muscle is now reflected laterally, bringing into view the structures about the coracoid process and the anterior portion of the capsule of the joint.

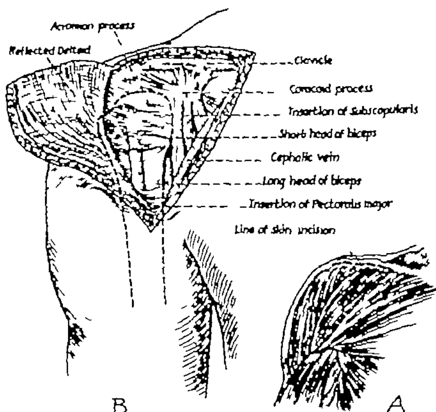


Fig. 13_.—Anteromedial approach to shoulder. *A*, Vertical arm of incision lies over interval between deltoid and pectoralis major muscles. *B*, Deltoid muscle detached from clavicular origin and retracted laterally exposing anterior aspect of joint.

The above approach affords adequate exposure of the anterior portion of the joint. If a wider field is needed the incision may be extended as suggested by Cubbins.

Technic (Cubbins et al.).—The anterior limb of the Cubbins exposure is similar to the anteromedial incision described above. The skin incision is extended around the lateral end of the acromion process and medially along the lateral half of the spine and the scapula. The origin of the deltoid muscle is further detached from the acromion and from that portion of the spine of the scapula which is exposed by the skin incision. The deltoid is then reflected down

ward and laterally thus revealing the anterior superior and posterior portions of the capsule of the joint. Access to the joint anteriorly or posteriorly may be obtained by a corresponding incision of the capsule, or the articular surface of both humerus and glenoid may be inspected by a continuous incision of the capsule from the anterior aspect of the joint, upward over the head of the humerus, and downward behind the head. In the latter event care should be taken to avoid severance of the tendon of the long head of the biceps muscle. At no point throughout the incision are the fibers of the deltoid divided further the axillary nerve, which supplies the deltoid is undisturbed.

Any part of this incision may be used for operations on limited regions about the shoulder joint. For example, Roberts utilized that portion which exposes the acromioclavicular joint and coracoid process for repair of ruptured ligaments associated with dislocation of the acromioclavicular joint.

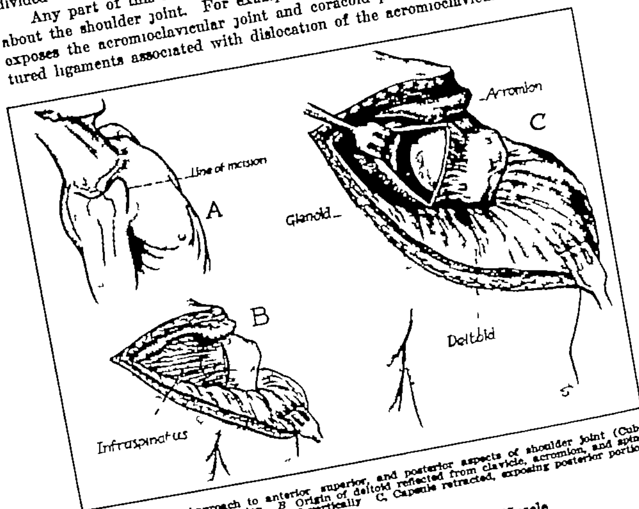


Fig. 132.—Approach to anterior superior, and posterior aspects of shoulder joint (Cubbins et al.) A, Skin incision. B Origin of deltoid reflected from clavicle, acromion, and spine of scapula posterior capsule incised vertically C, Capsule retracted, exposing posterior portion of glenoid and humerus.

Anterior Approach Through the Deltoid Muscle

This approach is employed for operations upon the muscles attached to the greater tuberosity of the humerus and for access to the subdeltoid bursa.

Technic.—Beginning at the acromioclavicular joint, the incision is carried downward for a distance of approximately two inches over the inner third of the deltoid muscle. The fibers of this structure are divided exposing the greater tuberosity and the upper portion of the shaft of the humerus. Unless unavoidable, the deltoid muscle should not be split more than 1¼ inches from its origin, as further longitudinal splitting of the muscle will tend to paralyze that portion

which lies anterior to the incision If further splitting is necessary, one should take care to protect the major branches of the axillary nerve By internal rotation of the humerus and flexion of the elbow to 90 degrees, the bicipital groove is exposed and the greater tuberosity, with the insertions of the supraspinatus, the infraspinatus, and the teres minor tendons is readily accessible External rotation of the humerus brings into view the lesser tuberosity with the insertion of the subscapularis tendon For a more extensive operative field, the deltoid may be stripped from its attachment to the acromion and clavicle The upper inch of the shaft may be exposed by continuing dissection down to the bone though care should be taken to isolate and retract the anterior circumflex humeral vessels and the anterior branch of the axillary nerve

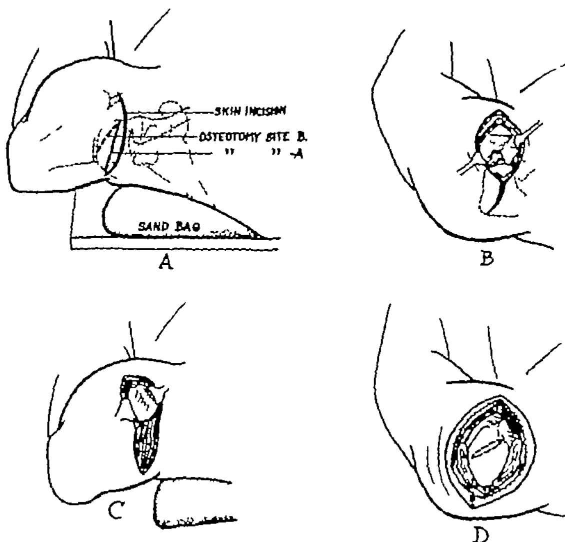


Fig 131.—Transacromial approach to shoulder joint. *A* Skin incision. *B* Fibers of deltoid separated. *C* Osteotomy of acromion. *D* Line of incision through coracohumeral ligament. Detached segment of acromion is usually discarded. (From McLaughlin, Harrison L. J Bone & Joint Surg 26 31, 1944.)

Transacromial Approach

The transacromial approach is derived from the Codman saber-cut approach and the Kocher posterior approach to the shoulder

Technic (McLaughlin).—The skin is incised along the "suspender line" just lateral to the acromioclavicular joint extending from the posterior aspect of the acromion to a point 3 to 5 cm below the anterior edge of the acromion,

The anterior distal limb of the incision is deepened through the deltoid muscle the latter is detached from the acromion process and the coraco-acromial ligament is divided. When complete exposure of the joint is necessary, the acromion is divided through site A and removed (Fig 134), for repair of the cuff, a more oblique osteotomy (site B) provides adequate exposure and a better cosmetic result.

A view of the joint is provided by dividing any of the cuff tendons in the line of their fibers this is best accomplished by an incision between the subscapularis and supraspinatus tendons, viz., through the coracohumeral ligament.

Closure of the cuff is accomplished by side-to-side suture The stump of the acromion is beveled, and the edge of the deltoid is sutured to the fascia on the remnant of the acromion.

This is an excellent approach for surgery of the musculotendinous cuff and fracture-dislocations of the shoulder

Saber-Cut Approach

The saber-cut approach was probably so named because of its similarity to saber wounds, which formerly were encountered in military surgery The subsequent technic is essentially that described by Codman

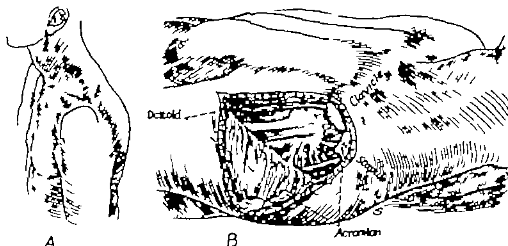


Fig. 135 —Saber-cut incision. A Skin incision. B, Separation of acromioclavicular joint and division of base of acromion, permitting lateral and posterior reflection of deltoid muscle and acromion process.

Technic.—The incision, which is in the shape of an inverted U is begun three inches below the head of the humerus, carried over the medial third of the deltoid muscle thence above the acromioclavicular joint, and downward over the posterior third of the deltoid muscle, terminating two inches below the level of the acromion. The subcutaneous tissues are divided to the deltoid muscle the fibers of the muscle are separated from above distally the acromioclavicular joint is disarticulated and the acromion process severed from the spine of the scapula by means of a Gigli saw the entire mass is then retracted laterally Care should be taken to avoid injury to the suprascapular nerve and transverse scapular artery as they wind through the greater scapular notch

To expose the joint, the capsule is opened across its superior surface. If a broader view is desired, the tendons attached to the greater tuberosity may

be separated at their insertion also, by rotation of the humerus, the insertion of the subscapularis tendon may be detached from the lesser tuberosity

A disadvantage of this incision, in common with all others which split the deltoid muscle, is the severance of the nerve supply to the muscle anterior to the incision The axillary nerve which supplies the muscle enters at its posterior margin and passes forward along the deep surface of the deltoid, if the muscle fibers are split too far downward, the main nerve trunk will be severed Even in incisions which divide the muscle above the main trunk of the nerve, a few fibers anterior to the incision may be deprived of their nerve supply

Posterior Approach

Similar posterior approaches to the shoulder joint have been described by Kocher McWhorter Bennett, Rowe and Yee, Harmon and others.

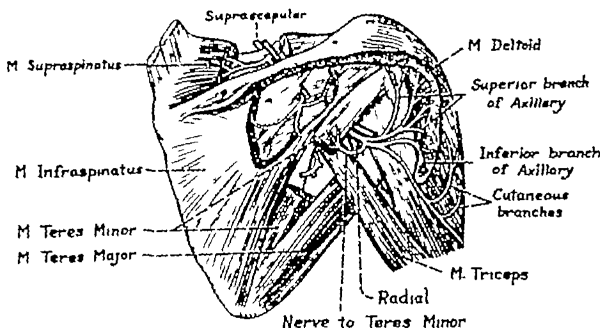


Fig. 136.—Anatomy of the posterior aspect of shoulder joint. (Adapted from Gray's Anatomy of the Human Body Philadelphia, 1936 Lea & Febiger)

Technic.—The skin incision begins just lateral to the tip of the acromion, passes medially along the outer border of the acromion and continues medially curving slightly downward just below the spine of the scapula, and ending at the base of the spine of the scapula. The skin and fascia are reflected, exposing the origin of the deltoid muscle from the spine of the scapula That portion of the deltoid which arises from the spine of the scapula is detached from the bone by subperiosteal dissection and is reflected downward and laterally In reflecting the deltoid, care is taken to avoid injury to the axillary nerve and vessels as they emerge from the quadrangular space and enter the substance of the muscle As a precaution against injury to this nerve the deltoid is not retracted below the level of the teres minor muscle Also, one should not enter the infraspinatus muscle, otherwise, the suprascapular nerve may be injured. After reflection of the deltoid muscle the posterior surface of the capsule of the shoulder joint may be exposed by detachment of the upper two-thirds of the infraspinatus tendon near its insertion into the humerus, and reflection of the detached portion of the infraspinatus medially The posterior surface of the

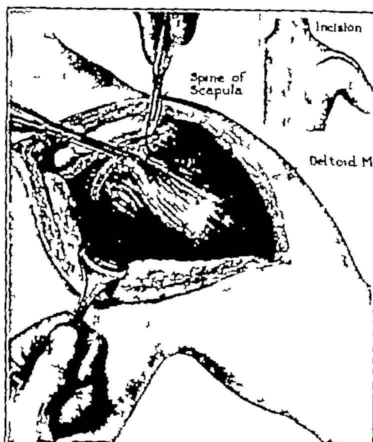


Fig. 137.—Posterior approach to shoulder joint. Deltoid muscle is detached from acromion and spinous process of scapula. Insert shows skin incision. (From Bennett, G. E. J. A. M. A. 117: 510, 1941.)

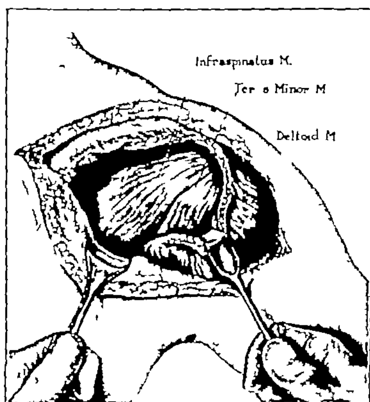


Fig. 138.—Same as Fig. 137. Deltoid muscle retracted to expose interval between infraspinatus and teres minor muscles. (From Bennett, G. E. J. A. M. A. 117: 510, 1941.)

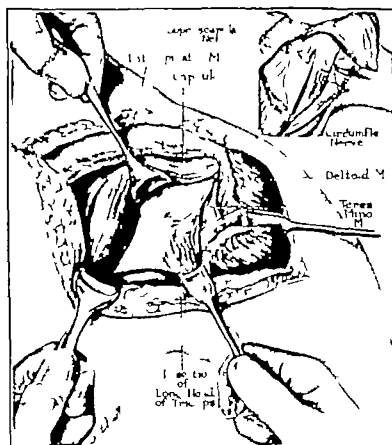


Fig. 139.—Same as Fig 137 Tendons of teres minor and infraspinatus muscles retracted to expose posterior capsule of houlder joint. Insert shows relation of circumflex nerve and suprascapular nerve to operative field. (From Bennett, G E.: J A. M. A. 117: 510, 1941.)

shoulder joint may also be exposed by an oblique incision between the infraspinatus and teres minor muscles. The capsule of the joint may then be opened by either a vertical or a transverse incision, or by a combination of both depending upon the exposure desired To gain access to the posterior portion of the capsule of the joint, dissection is carried between the infraspinatus and teres minor muscles. One thus avoids injury to the nerve supply of these muscles, as the infraspinatus receives its nerve supply from the suprascapular nerve above, while the teres minor muscle receives its supply from the axillary nerve below (Fig 139)

Approach to Acromioclavicular Joint

Technic (Roberts)—A curved incision is made along the anterior superior margin of the acromion and distal one-fourth of the clavicle The origin of the deltoid is exposed and severed from the clavicle and anterior margin of the acromion, bringing into view the capsule of the acromioclavicular joint. By retraction of the deltoid downward the coracoid also may be exposed.

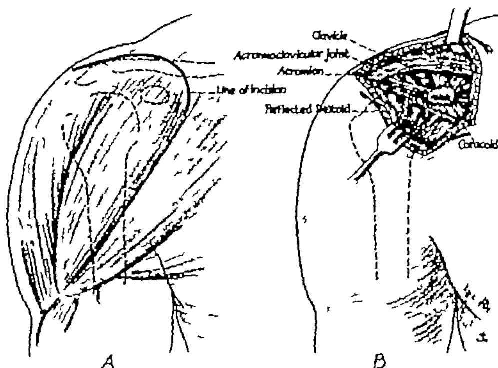


Fig. 146.—Exposure of acromioclavicular joint and coracoid process of scapula (Roberts) A Skin incision. B Deltoid muscle detached from clavicle and acromion, exposing acromioclavicular joint, and being retracted distally for exposure of coracoid process. (Redrawn from Roberts, Sumner M Am. J Surg. 23: 322, 1934.)

ELBOW

Posterolateral Approach

Campbell employed a posterolateral incision for exposure of the elbow joint, especially for treatment of old posterior dislocations, arthroplasties, fractures of the lower end of the humerus involving the elbow joint, as well as other extensive operations upon the joint

Technic.—The skin incision is begun four inches above the elbow on the posterolateral aspect and continued distally for five inches. Dissection is

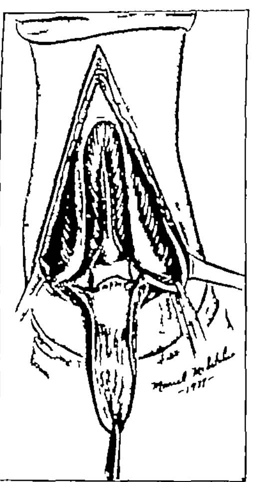


Fig 141

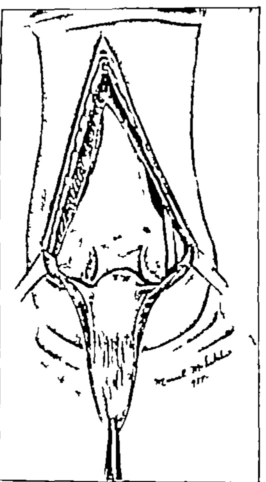


Fig 142

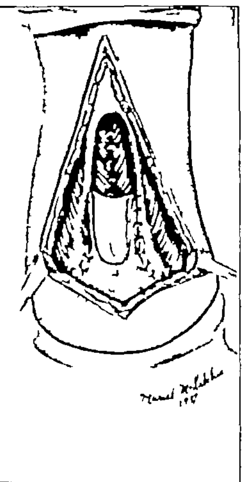


Fig 143

Fig 141.—Posterior approach to elbow U shaped tongue of triceps aponeurosis dissected free and reflected distally (From Van Gorder G W J Bone & Joint Surg 22: 278 1940.)

Fig 142.—Same as Fig 141 Elbow joint and lower end of humerus exposed by subperiosteal dissection ulnar nerve identified and protected. (From Van Gorder G W J Bone & Joint Surg 22: 278, 1940.)

Fig 143.—Same as Fig 141 Triceps continuity re-established by layer of deep sutures through muscle. Tongue of triceps aponeuro sutured into its original position. (From Van Gorder G W: J Bone & Joint Surg 22: 278, 1940.)

carried down through the fascia, exposing the aponeurosis of the triceps muscle to its insertion into the olecranon process of the ulna In the presence of contracture of the triceps muscle from fixed extension of the elbow the aponeurosis is freed from above downward in a tongue like flap and retracted

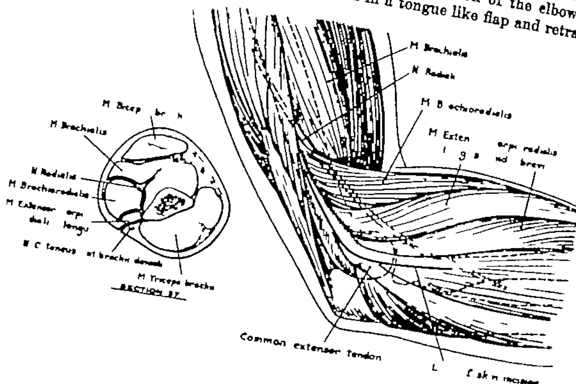


Fig 144.—Lateral approach to elbow Cross Section 57 shows relation of surgical dissection to adjacent anatomy at level of proximal portion of incision. Section 58 is through level of arm just above condyles. (Cross sections from Eycleshymer A. C., and Schoemaker D. M. New York, 1930, Appleton-Century-Crofts, Inc.)

distally to its insertion into the olecranon process. The remaining fibers of the muscle are incised to the bone in the midline If the triceps muscle is not contracted the muscle and aponeurosis may be divided longitudinally in the midline and dissection is continued through the periosteum of the humerus and

through the capsule of the elbow, thence along the external border of the olecranon process. The periosteum, together with the triceps muscle is elevated from the lower extremity of the humerus posteriorly for two inches, exposing the joint For a more extensive view the subperiosteal stripping may be continued on each side releasing the muscular and capsular attachments to the condyles and exposing the anterior surface Care must be taken not to injure the ulnar nerve One should be as conservative as possible in denuding the bone as an excessive amount of subperiosteal dissection may cause serious damage to the blood supply of the bone and subsequent avascular necrosis. The head of the radius is exposed at the distal end of the incision

In those cases wherein the elbow is fixed in complete extension, the elbow is flexed to 90 degrees following operation The inverted V shaped portion of the triceps fascia is then used to fill the lower portion of the defect in the triceps tendon while the upper portion is closed by approximation of the two margins of the triceps as shown in Fig 256

Lateral Approach

Technic.—The incision begins three to four fingerbreadths* above the lateral epicondyle of the humerus, extends down the lateral surface of the arm to the epicondyle thence down the posterolateral surface of the forearm a distance of two to three fingerbreadths. The tip of the lateral epicondyle is exposed The interval between the triceps posteriorly and the origin of the extensor carpi radialis longus and brachioradialis anteriorly, is developed from below upward bringing into view the lateral border of the humerus. In the upper angle of the incision one must avoid damage to the radial nerve as it enters the interval between the brachialis and brachioradialis muscles (Fig 144) With a small osteotome the common origin of the extensor muscles from the lateral epicondyle may be separated from the humerus together with a thin fleck of bone or the common origin may be divided just distal to the medial epicondyle In either event the common origin is displaced distally revealing the radiohumeral joint One should be careful to protect the deep branch of the radial nerve as it enters the two planes of the supinator muscle.

The origins of the brachioradialis and extensor carpi radialis longus are elevated subperiosteally and the capsule is divided, exposing the lateral aspect of the elbow joint In closing the wound, the origin of the extensor muscles is reattached.

This is an ideal approach for fracture of the external condyle of the humerus, as the common extensor origin is attached to the condylar fragment and need not be disturbed.

Lateral J Approach

Technic (Kocher).—This approach begins two inches above the elbow on the lateral supracondylar ridge of the humerus, extends distally along this ridge is continued below the head of the radius a distance of two inches, then curved medially across the posterior surface of the ulna ending at the medial border of the ulna. Dissection is carried down between the triceps posteriorly and the brachioradialis and extensor carpi radialis longus muscles anteriorly,

* Fingerbreadths of patient.

bringing into view the external condyle and the capsule over the lateral surface of the head of the radius. Below the head, the extensor carpi ulnaris and anconeus muscles are separated and the lower fibers of the anconeus are divided in the direction of the curved and transverse portions of the lower end of the skin incision The periosteum is reflected from the anterior and posterior surfaces of the distal end of the humerus. The entire group of extensor muscles which arises from the external condyle is reflected anteriorly either by subperiosteal dissection or by detachment of the external condyle. *The capsule of the joint is incised longitudinally* The anconeus is then reflected subperiosteally from the upper portion of the ulna, permitting dislocation and examination of the joint under direct vision.

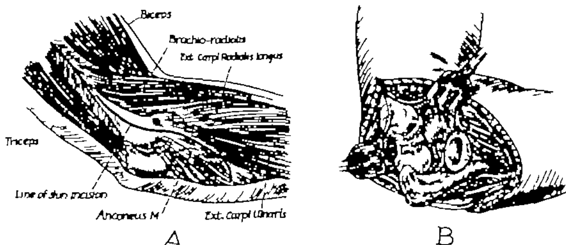


Fig. 145—Lateral J ncision (Kocher) *A* Relation of skin incision to deep structures. *B* Exposure of joint after reflection of muscles, incision of joint capsule, and dislocation of elbow

Medial Approach With Severance of the Internal Epicondyle

This exposure was developed independently by Molesworth and by Campbell. The occasion for both discoveries was an operation for fracture of the internal epicondyle of the humerus. In Campbell's case the fragment had rotated and displaced downward and outward into the joint cavity carrying the attachment of the flexor group of muscles of the forearm and a portion of the internal capsule into the joint these were interposed between the sigmoid cavity of the ulna and the trochlear surface of the humerus. During the operation it was demonstrated that the radius and ulna could be dislocated outward on the humerus, and that not only could the entire articular surface of the bones be inspected but all portions of the joint as well. Recognizing the advantages of this complete exposure, Campbell on several occasions employed a similar approach to the interior of the joint, for removal of loose bodies or other surgical procedures

Technic.—*With the elbow flexed at 90 degrees, a medial incision* is made from two inches below to approximately two inches above the elbow over the tip of the internal epicondyle The ulnar nerve is isolated in the groove posterior to the condyle dissected free and retracted posteriorly The soft tissues, with the exception of the common tendinous origin of the flexor muscles of the forearm, are dissected from the epicondyle and with a small osteotome, the epicondyle is detached and reflected downward its tendinous

attachments remain undisturbed Blunt dissection is next continued downward, reflecting the muscles which originate from the medial condyle The branches of the median nerve which supply the muscles, entering along their lateral margins, should be protected The inner aspect of the coronoid process is freed, the capsule incised and the periosteum with the anterior and posterior capsule stripped from the humerus as far as necessary Care must be taken to avoid injury to the median nerve as it passes over the anterior aspect of the joint. With the external capsule acting as a hinge the joint may now be dislocated outward

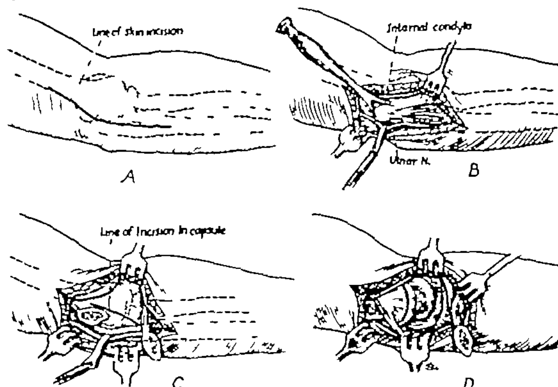


Fig. 146 —Medial approach to elbow joint (Campbell) *A* Skin incision. *B* Ulnar nerve retracted posteriorly, internal condyle severed. *C* Condyle with attached origin of flexor muscles retracted distally medial capsule incised longitudinally *D* Exposure of entire joint after dislocation of elbow

Medial and Lateral Approaches

Technic.—When extensive exposure is not required incisions of two to three inches in length may be made on either or both sides of the joint, just anterior to the condyles and parallel with the condylar ridges of the humerus. On the medial side the ulnar nerve must be carefully avoided. The capsule is incised from above downward on each side exposing the joint.

Posterior U Approach

A posterior U-approach in which the olecranon is severed, has been described by MacAusland for use in arthroplasty of the elbow

Technic (MacAusland).—A semicircular incision is begun over the external condyle of the humerus, carried distally two inches, thence upward over the internal condyle. The skin and fascia are dissected up proximally the ulnar nerve being isolated and retracted medially Following the direction of the skin incision, the subcutaneous structures are divided to the bone. The tip of the olecranon is removed with a saw and retracted proximally together with all soft structures.

tensor pollicis brevis tendons laterally and the radial collateral ligament medially. One must also preserve the superficial branches of the radial nerves which supply the skin over the thumb.

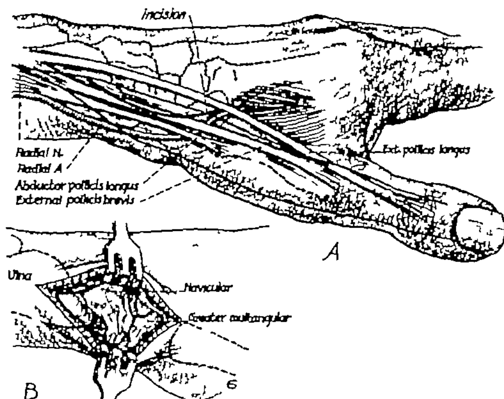


FIG. 149.—Lateral approach to wrist. *A*, Line of skin incision in relation to deep structures. *B*, Exposure of navicular, greater multangular and distal end of radius.

Medial Approach

Technic.—The skin incision is made directly over the lower extremity of the ulna and upper extremity of the fifth metacarpal bone. There are no intervening structures except the fasciae. The capsule is opened longitudinally. Care is taken not to injure the intra articular fibrocartilage, which is attached to the styloid process of the ulna.

THE BONES

APPROACHES TO THE OS CALCIS

Medial Approach

Technic.—Beginning at the tendo achillis, this incision is carried along the medial surface of the foot just below the sustentaculum tali to one inch anterior to and one and one-half inches below the medial malleolus. The fat and fascia are divided and the periosteum is incised revealing the calcaneus.

Lateral Approach

Technic.—The lateral incision begins on the lateral margin of the tendo achillis near its insertion and passes forward to a point one and one-half inches below and one inch anterior to the external malleolus. The superficial and

deep fasciae are divided the peroneal tendons isolated, and the periosteum is incised below the tendons and elevated to expose the bone If necessary and if no infection is present, the tendons may be cut and resutured

U Approach

Technic.—For access to the plantar surface of the calcaneus the above approaches are joined, forming a large "U" shaped incision about the posterior four fifths of the bone The flap of skin with the fatty heel pad is retracted from the bone

Split Heel Approach

The split heel approach is seldom used except for osteomyelitis of the os calcis.

Technic (Gaenslen).—The patient should lie in the prone position and a support should be placed under the ankle The incision is begun on the plantar surface of the foot opposite the tuberosity at the base of the fifth metatarsal bone on a line bisecting the heel and middle toe and is carried over the heel, splitting the lower end of the tendo achillis one to one and one half inches. The plantar aponeurosis is incised between the abductor muscle of the small toe and the short flexor group to all the toes. The lateral plantar artery and nerve may be seen in the distal angle of the wound these should be retracted medially Fibers of the quadratus plantae muscle are exposed and split longitudinally with the long plantar ligament. With a broad chisel, the calcaneus is divided from behind forward. Retraction of the two halves gives a full view of the interior of the bone. By further retraction, access to the subastragalar joint is obtained The plantar scar is so deeply situated after healing that the tissues on each side form two thick cushions, well adapted to weight bearing without pain

Kocher Approach

This procedure is suitable for complete excision of the calcaneus.

Technic.—The skin over the medial border of the tendo achillis is incised from three inches above the tuberosity of the calcaneus to the lower posterior portion of the tuberosity the incision is then continued transversely around the posterior aspect of the calcaneus, thence forward along the lateral surface of the foot to the tuberosity of the fifth metatarsal bone The tendo achillis is severed at its insertion and dissection is carried down to the bone To reach the superior surface, all tissues beneath the severed tendo achillis are freed The calcaneus may then be enucleated with or without its periosteal attachments (See Fig 118)

APPROACH TO THE TIBIA

The tibia is a superficial bone, and is easily exposed throughout without fear of damage to any structure.

Technic.—A curved incision may be made on either side of the anterior border the skin is reflected and the periosteum incised and elevated over the desired area. *Stripping* of the periosteum should be restricted to the minimum requirement as regeneration of the bone is materially influenced by the circulation which comes through this source

APPROACH TO THE FIBULA

Posterolateral Approach

Technic (Henry).—The skin is incised along the posterior margin of the fibula from five inches above the lateral malleolus, to the posterior margin of the head of the fibula, thence upward along the posterior aspect of the biceps tendon a distance of four inches. The superficial and deep fasciae are divided. The common peroneal nerve is isolated along the posteromedial aspect of the biceps tendon in the upper portion of the wound, and is freed downward to its entrance into the peroneus longus muscle. With the knife blade pointed

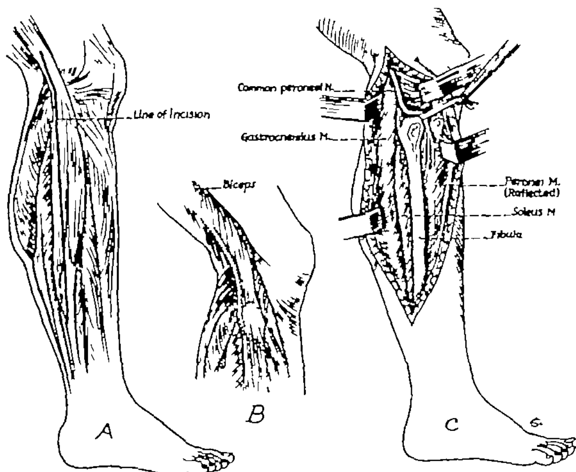


Fig. 150—Posterolateral approach to fibula (Henry) *A* Skin incision. *B* Course and relationship of common peroneal nerve. *C*, Origin of peroneus longus muscle proximal to peroneal nerve divided and reflected anteriorly nerve retracted proximal and anterior to head of fibula shaft of fibula exposed by development of plane between soleus and peroneal muscles.

upward and anteriorly that portion of the peroneus longus muscle which *arises from the lateral surface of the head of the fibula above the common* peroneal nerve is detached The nerve may then be retracted over the head of the fibula. The fascial plane between the soleus muscle posteriorly and the peronei anteriorly is located and dissection is carried downward along this plane to the fibula. The bone is exposed by retraction of the peronei anteriorly and incision of the periosteum In retracting these muscles, one must avoid injury to the branches of the common peroneal nerve which lie on the deep surface of the peroneal muscles *and are in close contact with the neck* of the fibula and upper two inches of the shaft.

The lower one-fourth of the fibula is subcutaneous on its lateral aspect and may be exposed by a longitudinal incision through the skin, fascia, and periosteum

APPROACHES TO THE FEMUR

Anterolateral Approach

This approach affords access to the middle third of the femur

Technic (Thompson) —The skin is incised over the middle third of the femur in a line between the anterior superior iliac spine and lateral margin of the patella The superficial and deep fasciae are incised and the rectus femoris and vastus lateralis muscles are separated along their intermuscular septum. The vastus intermedius muscle, which is thus brought into view, is divided in the line of its fibers down to the femur The anterolateral aspect of the femur may then be exposed by subperiosteal reflection of the incised vastus intermedius muscle.

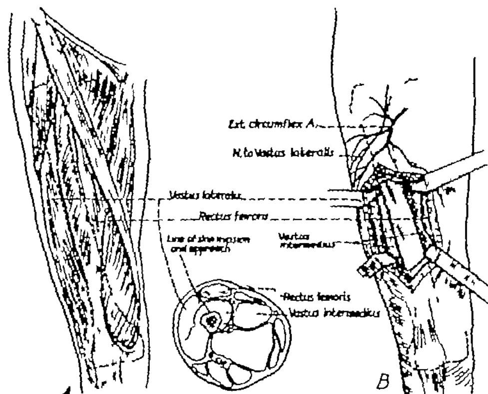


Fig. 151 —Anterolateral approach to femur A Skin incision. B Femur exposed by separation of rectus femoris and vastus lateralis muscles and division of vastus intermedius muscle. (Cross section from Eycleshymer A. C., and Schoemaker D. M., New York, 1911; D. Appleton & Co.)

Henry exposes the entire shaft of the femur by prolonging this incision proximally and distally The procedure is not recommended for operations on the proximal third of the femur, since exposure of the bone in this area is difficult without injury to the external circumflex artery and the nerve to the vastus lateralis muscle. Distally the incision may be prolonged to within five or six inches of the knee joint at this point, however, the insertion of the vastus lateralis muscle into the quadriceps tendon is encountered Further in attempting to expose the lower five or six inches of the femur one is likely to penetrate the suprapatellar pouch

Lateral Approach

Technic.—An incision of the desired length is made over the lateral aspect of the thigh along a line extending from the greater trochanter to the external condyle of the femur The superficial and deep fasciae are incised. The vastus lateralis and vastus intermedius muscles are divided in the direction of their fibers and the periosteum is opened and reflected for the proper distance A branch of the external circumflex artery is encountered in attempting to reach the upper fourth of the femur and the lateral superior genicular artery is encountered in an approach to the lower fourth these may be clamped divided, and ligated without harm

Anatomically exposure of the entire shaft of the femur is possible through this approach Since surgical shock may accompany such a procedure, the incision is recommended only for less extensive operations upon the bone

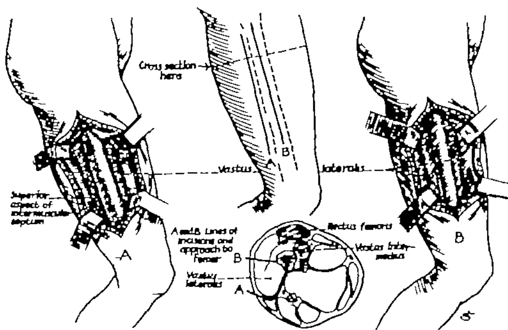


Fig. 152.—Posterolateral and lateral approaches to middle third of femur *A* Posterolateral exposure along lateral intermuscular septum. *B* Lateral exposure after incision of vastus lateralis muscle. Insert shows cross sections of skin incisions and line of approach in *A* and *B*. (Cross section from Fycleshyme A. C., and Schoemaker D. M. New York, 1911, D. Appleton & Co)

Posterolateral Approach

Access to the entire shaft of the femur may be obtained by an incision on the posterolateral aspect of the thigh.

Technic.—The patient is turned slightly on the unaffected side. The incision is made from the base of the trochanter distally to the external condyle, and the superficial fascia and fascia lata are incised along the anterior border of the iliotibial band, bringing into view the posterior portion of the vastus lateralis muscle This structure is retracted anteriorly and dissection is continued down to the bone along the anterior surface of the lateral intermuscular septum which is attached to the linea aspera. By retraction of the deep structures anteriorly the periosteum may be split in the line of the incision. With a periosteal elevator the attachment of the vastus intermedius muscle is stripped free as far as necessary

A disadvantage of this incision lies in the fact that the vastus lateralis muscle is difficult to retract in muscular patients, further, a number of terminal branches from the perforating artery are divided as they pass laterally into the vastus lateralis muscle

Posterior Approach to the Femur

Technic (Bosworth) —With the patient in the prone position the skin and deep fascia are incised longitudinally in the center of the posterior aspect of the thigh from just below the gluteal crest to the upper margin of the popliteal space The long head of the biceps femoris muscle is used as a guide to this approach. By blunt dissection with the index finger, the posterior surface of the femur may be palpated at the middle of the thigh The middle three-fifths of the linea aspera which is covered by the attachment of the vastus medialis and lateralis muscles, may be exposed by retraction with the fingers To expose the upper portion of the middle three-fifths of the femur, the blunt dissection is carried along the lateral border of the long head of the biceps, developing the fascial plane between the long head of the biceps and the vastus lateralis muscle, and the long head of the biceps is reflected medially (Fig 153) To expose the lower portion of the middle three-fifths of the femur dissection is carried out along the medial surface of the long head of the biceps, developing the fascial plane between the long head of the biceps and the semitendinosus, and the long head of the biceps and the sciatic nerve are retracted laterally (Fig 155) If exposure of the entire middle three fifths of the femur is desired blunt dissection to the linea aspera is carried lateral to the long head of the biceps the latter muscle is divided in the lower portion of the wound and together with the sciatic nerve, is displaced medially (Fig 154) The nerve supply to the short head of the biceps crosses the exposure near its center this branch of the sciatic nerve may be saved or divided, depending upon the requirements of the incision, as it does not comprise the entire nerve supply of the short head of the biceps. After exposure of the linea aspera the muscle attachments are freed by sharp dissection and the femur is exposed by subperiosteal dissection

Bosworth points out that the middle three-fifths of the femur should *never* be exposed by the lateral retraction of the long head of the biceps and the sciatic nerve as this procedure subjects the sciatic nerve to unnecessary danger When the lower end of the long head of the biceps is divided, sutures should be placed in the distal fragment of the muscle before the division is carried out. This facilitates suture of the muscle in closure of the wound The long head of the biceps having been sutured in place, the wound is closed by suture of the skin alone, as the other structures fall into position

In developing this approach the surgeon must keep in mind the ever present possibility of danger to the sciatic nerve rough handling and prolonged or strenuous retraction may cause distressing postoperative symptoms, or possibly permanent disability in the leg

Lateral Approach to the Posterior Surface of the Femur in the Popliteal Space

Technic (Henry) —With the knee slightly flexed the skin and superficial fascia are incised for a distance of six inches along the posterior edge of the

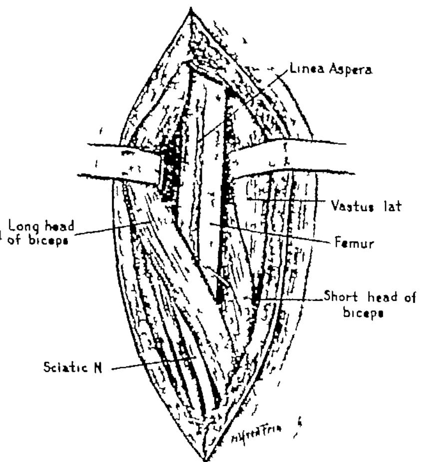


Fig. 153.

Sciatic N
Femur
Vastus lateralis
Long head of biceps
Short head of biceps

Fig 154

Fig. 153.—Bosworth posterior approach to femur Fo skin incision, see Fig 154. Exposure of proximal portion of middle three-fifths of femur obtained by medial retraction of long head of biceps. (From Bosw rth, D. M.: J Bone & Joint Surg 26: 687 1944.)

Fig 154.—Same as Fig. 153. For complete exposure of middle three-fifths of femur posteriorly by Bosworth pproach, lowe attachment of long head of biceps must be divi led and retracted medi lly togethe with sciatic nerve. (From Bosworth, D M. J Bone & J i t Surg. 26 687 1944.)

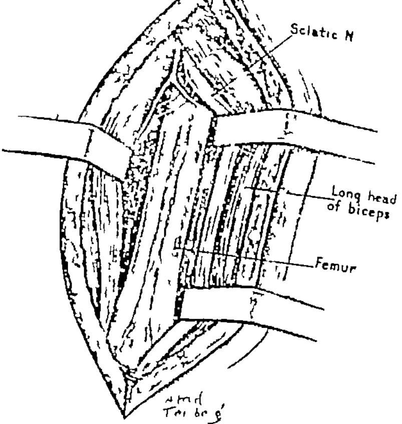


Fig. 155.

Semitendinosus
Semimembranosus
Long head of biceps
Sciatic N
Linea Aspera
Short head of biceps

Fig. 156.

Fig. 155.—Same as Fig. 153. Distal portion of middle three-fifths of femur exposed by lateral retraction of long head of biceps and sciatic nerve. (From Bosworth, D. M.: J. Bone & Joint Surg. 26: 687, 1944.)

Fig. 156.—Same as Fig. 153. The sciatic nerve will be exposed to injury if entire middle three-fifths of femur is exposed by lateral retraction of biceps; this should never be done. Insert shows line of skin incision. (From Bosworth, D. M.: J. Bone & Joint Surg. 26: 687, 1944.)

iliotibial band, following the angle of the knee to the head of the fibula. The deep fascia is divided immediately behind the iliotibial band. Just above the condyle the attachment of the short head of the biceps is separated from the posterior surface of the lateral intermuscular septum the popliteal space is reached by blunt dissection between these structures. The branches of the perforating vessels are ligated and divided while the popliteal vessels are retracted backward in the posterior wall of the wound The tibial nerve lies posterior to the popliteal vessels, and the common peroneal nerve follows the medial edge of the biceps. The surface of the femur is exposed by incision and elevation of the periosteum

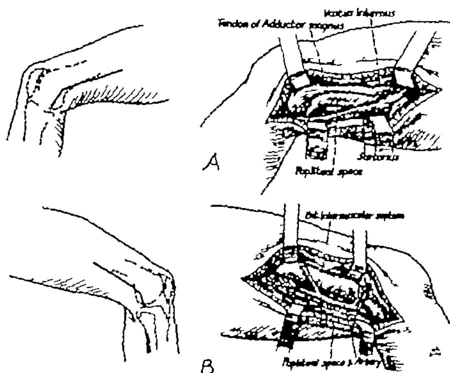


Fig. 147 —Approaches to lower one-fourth of femur (Henry) A Medial incision. B Lateral incision.

Medial Approach to the Posterior Surface of the Femur in the Popliteal Space

Technic (Henry) —Beginning six inches above the adductor tubercle, an incision is made along the adductor tendon, thence distally following the angle of the knee to two inches below the adductor tubercle In the lower portion of the incision, dissection is carried posteriorly to the anterior edge of the sartorius muscle just proximal to the level of the adductor tubercle. The deep fascia over this muscle is freed upward with care to avoid puncture of the synovial membrane, which is subjacent to torius muscle when the joint is flexed Following this procedure, the ill fall backward, ex posing the tendon of dductor magnus ie saphenous nerve follows the sartori eep surface an protected the great saphenous vein is d is not in incision is properly made The thin to the add is ne ed by blunt dissection to face of the pace. The large vessels retracted the muscles bone clamp

magnus tendon and a part of the vastus medialis muscle are retracted anteriorly giving access to the bone The tibial and common peroneal nerves are not encountered as they lie lateral and posterior to the line of incision

Lateral Approach to the Upper Portion of the Femur and Trochanteric Region

Technic—The incision begins about two inches above and anterior to the greater trochanter curves downward and posteriorly over the posterolateral

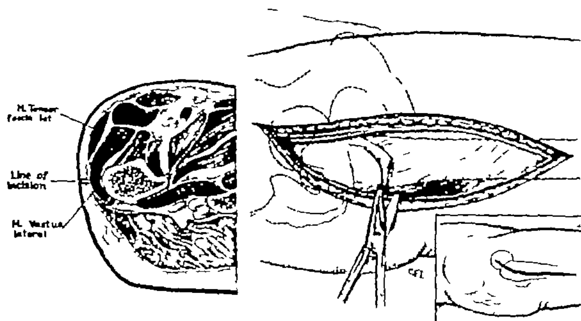


Fig. 158.—Lateral approach to upper portion of femur and trochanteric region. Insert shows line of incision. Vastus lateralis muscle incised transversely just distal to trochanter and separated longitudinally from posterolateral surface of femur one-fouth inch from linea aspera. Cross section shows line of approach at level of lesser trochanter Cross section drawn from Eycleshymer A. C. and Schoemaker D M New York, 1930 Appleton-Century Crofts, Inc.)

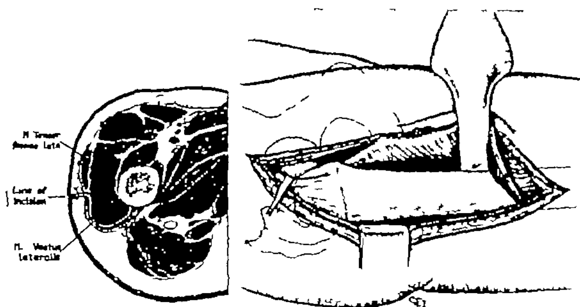


Fig. 159—Same a Fig 158. Exposure completed by subperiosteal dissection of vastus lateralis from femur Cross section of approach at level of distal limb of incision The hip may be exposed by continuing proximal limb of approach into a Watson-Jones incision. (Cross section drawn from Eycleshymer A. C., and Schoemaker D. M. New York, 1930 Appleton-Century-Crofts, Inc.)

aspect of the trochanter and thence down the lateral surface of the thigh, parallel with the femur for a distance of four inches or more depending upon the amount of femur to be exposed The dissection is extended in the line of the incision down to the fascia lata. In the lower portion of the wound, the fascia is incised with a scalpel, then split upward with scissors. In the upper portion of the wound the fascia is divided just posterior to the tensor fascia femoris muscle thus avoiding splitting of this muscle Retraction brings into view the vastus lateralis muscle and its origin from the inferior border of the greater trochanter The origin of the muscle is divided transversely along this border down to the posterolateral surface of the femur Beginning on its posterolateral surface, ¼ to ⅜ inch from its attachment to the linea aspera, the vastus lateralis is now divided with scissors. The muscle is thus divided in its thin portion rather than in its thick portion, as is the case in a direct lateral muscle splitting approach (cross-section Fig 158) Not more than ¼ inch of the muscle is sectioned at one time. The body of the vastus is kept retracted anteriorly, by this means, if one of the perforating arteries is divided it may be clamped before becoming loose enough to retract beyond the linea aspera After division along the femur for the required distance, the muscle is elevated with a periosteal elevator exposing the lateral and anterolateral surfaces of the femoral shaft.

The intertrochanteric line, together with the anterior surface of the femur just below this line is exposed by further subperiosteal elevation of the upper portion of the vastus lateralis and intermedius muscles. The base of the femoral neck may be exposed by division of the capsule of the hip joint at its attachment to the intertrochanteric line. If a wider exposure is desired, the lower portion of the gluteus minimus may be elevated from its insertion into the trochanter

In closure the vastus lateralis muscle falls over the lateral surface of the *femur and is sutured to the portion of this muscle which was left attached to* the femur just lateral to the linea aspera The fascia lata is then sutured and the remainder of the wound closed in routine manner

This is an excellent approach for reduction and internal fixation of trochanteric fractures, or for subtrochanteric osteotomies under direct vision

APPROACH TO THE ILIUM

Technic.—The skin is incised along the crest of the ilium from the anterior superior spine to the posterior superior spine. The attachments of the gluteal muscles are reflected subperiosteally from above downward to the superior rim of the acetabulum, bringing into view the outer surface of the ilium The attachments of the abdominal muscles are next reflected subperiosteally from the crest of the ilium and the iliacus muscle is similarly removed from the inner surface of the ilium The structures attached to the anterior superior iliac spine and anterior border of the ilium are also divided at their origins. Thus, the greater part of the ilium may be completely denuded

In this procedure, a nutrient artery on the external surface of the ilium two inches below the crest and near the juncture of the anterior and middle

thirds is severed Since ligation is impossible the bleeding usually is controlled by the point of a small hemostat. Rarely the use of bone wax may be required to control the hemorrhage.

APPROACH TO THE ISCHIUM

Technic (Milch) —See Chapter XIX

APPROACH TO THE HUMERUS

Anterolateral Approach

Technic (James E. Thompson, and Henry) —An incision is made in line with the medial border of the deltoid muscle from a point midway between its origin and insertion, downward to the level of the insertion, thence along the lateral border of the biceps muscle to within three inches of the elbow joint The superficial and deep fasciae are divided Care should be taken to

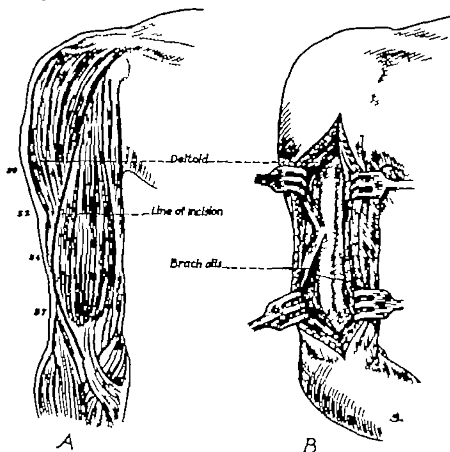


Fig. 160.—Anterolateral approach to shaft of humerous. A Skin incision. B, Deltoid and biceps muscles retracted brachialis muscle incised longitudinally exposing shaft.

preserve the cephalic vein, which approximately parallels the incision. In the upper portion of the wound the deltoid muscle is retracted laterally and the biceps medially revealing the shaft of the humerus. Distal to the insertion of the deltoid the brachialis muscle is exposed, split longitudinally to the bone, and displaced subperiosteally the lateral half to the outer side and the medial half to the inner side. This is more easily accomplished by flexion of the elbow to 90 degrees, which relaxes the tendon of the brachialis. The radial nerve as it winds about the shaft of the humerus is protected by the lateral half of the brachialis muscle.

If desired this incision may be prolonged to within two inches of the condyles of the humerus without entering the elbow joint. For further exposure of the proximal portion of the shaft, the incision may be extended upward, as in the anteromedial approach to the shoulder joint.

The advantages of this approach are (1) the brachialis muscle usually receives its nerve supply from both the musculocutaneous and radial nerves and may therefore be divided without causing paralysis of its fibers (2) the radial nerve is protected by the lateral half of the brachialis muscle

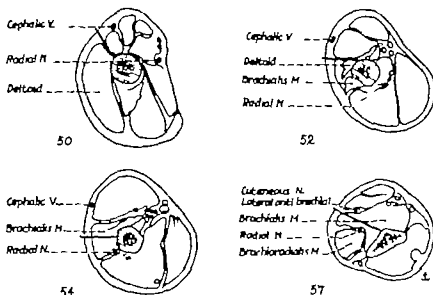


Fig 161.—Cross sections at various levels on arm (see Fig. 133) showing method of approach through deep structures, to avoid injury to radial nerve. (Redrawn from Eycleshymer Albert C., and Schoemaker Daniel M. New York and London, 1911 D. Appleton & Co.)

Approach to Upper and Middle Thirds of the Posterior Surface of the Radius

The upper third of the radius is covered by the supinator muscle through which the deep branch of the radial nerve passes. Because of these anatomic conditions, exposure of the upper third of the radius is extremely difficult in doing so one must constantly keep in mind the relation of the nerve to the supinator muscle and radius, exercising care to protect the nerve from undue trauma by retraction.

Technic (Thompson).—The incision extends over the upper and middle thirds of the forearm along a line drawn from the center of the dorsum of the wrist to a point one-half inch anterior to the external epicondyle of the humerus this is approximately in a straight line when the wrist is in pronation. The lateral (radial) border of the extensor digitorum communis tendon is exposed in the lower portion of the incision. The interval is developed between the common extensor tendon to the fingers and the extensor carpi radialis brevis, and these structures are retracted toward the ulnar and radial sides respectively The abductor pollicis longus muscle may then be seen and retracted distally and to the ulnar side to expose a portion of the posterior surface of the radius. Dissection is next continued upward between the extensor digitorum communis and extensor carpi radialis brevis and longus muscles to the lateral epicondyle of the humerus. The extensor digitorum

communis is reflected medially revealing the supinator muscles, or, if a better view is desired the extensor digitorum communis is detached at its origin on the external epicondyle and further retracted medially The area of the bone covered by the supinator muscle may be exposed by dividing the muscle fibers until the deep branch of the radial nerve is seen The nerve is carefully retracted Or the muscle may be freed from the bone subperiosteally and reflected either proximally or distally, this is the better procedure if sufficient exposure can be obtained

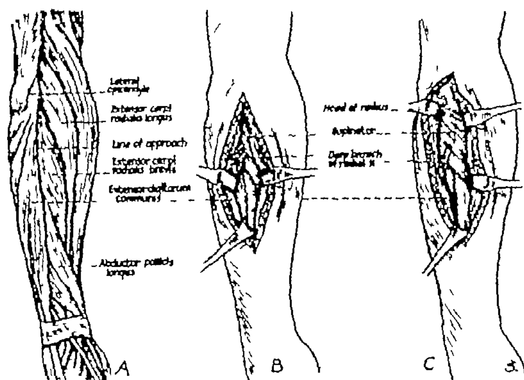


Fig. 162.—Approach to upper and middle thirds of posterior surface of radius (Thompson) A Skin incision. B and C Exposure of middle third of radius after retraction of muscles note relation of supinator muscle and deep branch of radial nerve to upper third of radius.

Approach to the Head of the Radius

The head and neck of the radius may be safely exposed by a posterolateral longitudinal incision

Technic.—An oblique incision is begun over the posterior surface of the lateral condyle of the humerus and continued obliquely downward and medially to a point over the posterior border of the ulna approximately three finger breadths below the tip of the olecranon The subcutaneous tissue and deep fascia are divided along the line of the incision, and the fascial plane between the extensor carpi ulnaris muscle and the anconeus is developed. This plane may be more easily found in the lower portion of the incision than in the upper portion where the two muscles blend together at their origin. The anconeus is retracted toward the ulnar side of the wound and the extensor carpi ulnaris muscle is retracted toward the radial side thus exposing the joint capsule in the depth of the upper portion of the wound. At this point fibers of the supinator muscle may be seen crossing at a right angle to the wound near its center and deep (anterior) to the extensor carpi ulnaris muscle. The upper fibers of the supinator muscles are retracted distally The joint capsule is now

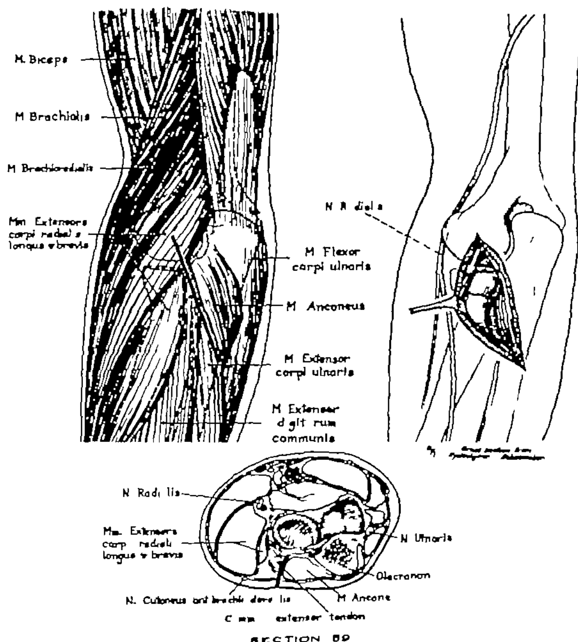


Fig 163.—Posterolateral approach to head of radius. Cross section shows relation of surgical dissection to adjacent anatomy (Cross section from Eycleshymer A. C. and Schoemake D. M New York, 1930 Appleton-Century-Crofts, Inc.)

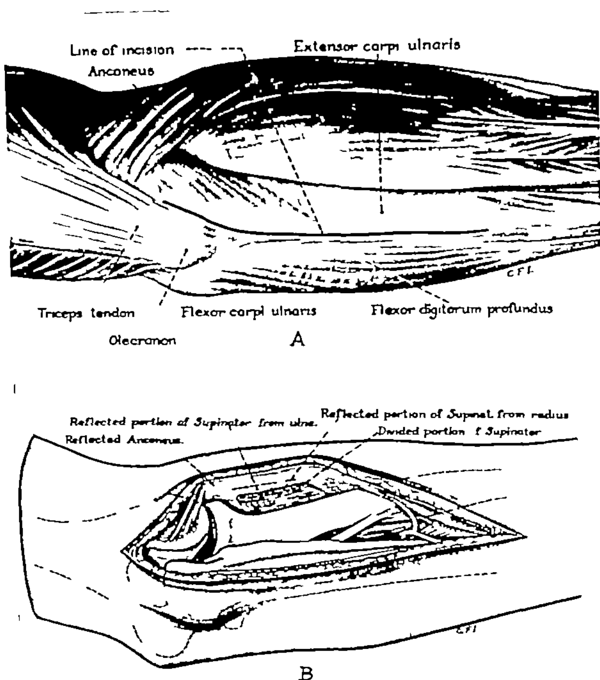
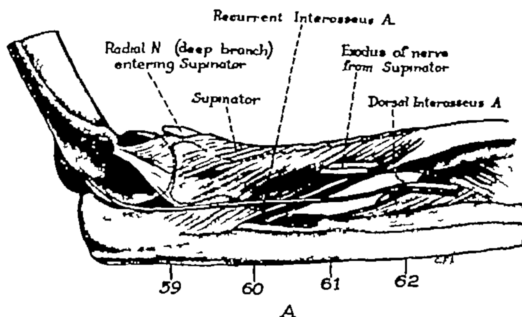


Fig 164.—Boyd exposure of ulna and proximal third of radius through one incision. A Skin incised along line of subcutaneous border of ulna. B Exposure of proximal third of ulna, upper one-fourth of radius, and radiohumeral articulation. (From Boyd, H. B. Surg Gynec. & Obst. 71 86, 1940.)



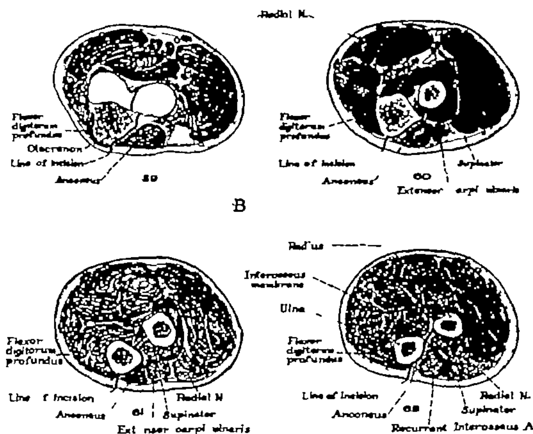


Fig. 165.—Same as Fig 164. Relation of deep branch of radial nerve to superficial and deep planes of supinator muscle. *A* Nos. *59*, *60*, *61* and *62* indicate levels of cross sections illustrated in *B*. (Cross sections from Lyclosbyner A. C., and Schoemaker D. M., New York, 1930 Appleton-Century-Crofts, Inc.)

located in the depth of the wound and incised, exposing the head and neck of the radius (Fig 163) The deep branch of the radial nerve, which lies between the two planes of the supinator muscle is not disturbed

APPROACH TO THE ULNA

A portion of the posterior surface of the ulna is practically subcutaneous throughout its length Any desired area of the bone may be approached by incision of the skin, fascia and periosteum along this surface.

Approach to Upper Third of the Ulna and Proximal Fourth of the Radius

Technic (Boyd) —The incision begins at a point about one inch above the elbow joint just lateral to the triceps tendon, thence continues downward over the

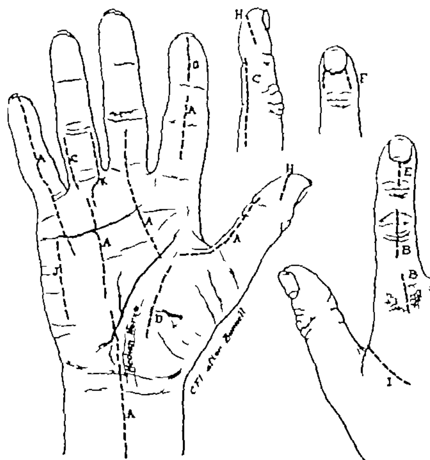


Fig. 166.—(Redrawn and captions quoted from Bunnell, Sterling J Bone & Joint Surg 14: 27 1932) "A chart of pernicious or incorrect incisions in the hand, any of which will do harm. *A* Median longitudinal incisions which cross flexion creases at right angles and result in flexion contractures. These are prevalent but pernicious. *B* Median incision on dorsum of finger which later leaves a scar that contracts and hinders flexion of the finger When present, it is impossible to fashion a proper skin flap under which to repair the extensor tendon. *C* Anterolateral incision in finger which is directly over and endangers the vessels and nerve. It is the usual one pictured for draining tendon sheaths, but should instead be mid-lateral. *D* Incision which thoughtlessly severs the motor thenar nerve and so robs the thumb of the power of opposition. *E* Median longitudinal incision through matrix will produce a ridged nail *F* Incisions for paronychia often pictured, but erroneous, as they do not drain the bottoms of the clefts formed by the borders of the base of the nail which curve strongly forward. *G* Median longitudinal incision in pulp for drainage of a felon. It will not drain as due to cleavage planes the pus progresses in spite of it and points dorsilaterally Also the scar resulting is in the tactile surface. *H* Alligator mouth incision wrongly placed too far anteriorly which leaves a scar in the tactile surface. *I* Incision across a web injures the web which itself has a function of complicated foldings to allow for movements of thumb. *J* Incision often made for drainage of pus in sheath of tendon to little finger The tendons, however converge sharply in palm to pass between the ridge of the trapezium and the unciform process of the unciform bone. *K* Incision continuous from finger to palm severs nerve, thus rendering half of finger permanently anaesthetic."

lateral side of the tip of the olecranon and along the subcutaneous border of the ulna, ending at the junction of the upper and middle third of this bone. The interval between the ulna on the medial side and the anconeus and extensor carpi ulnaris on the lateral side, is developed. The anconeus is stripped from the bone subperiosteally in the upper portion of the incision the head of the radius may be exposed by reflecting the anconeus laterally Below the head

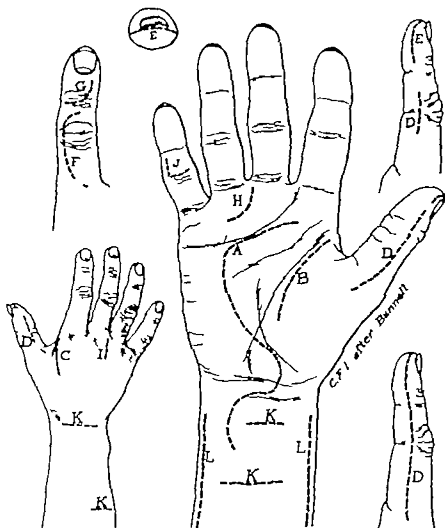


Fig. 167.—(Redrawn and captions quoted from Bunnell, Sterling J. Bone & Joint Surg. 14: 27, 1932.) A chart of advisable or correct incisions in the hand which will afford access and will not cause disability *A* Incision for approach into palm f r drainage of middle palmar space. It parallels the flexion creases, except in the immovable part or heel of the hand, allow wide opening by a triangular flap, and can be prolonged so as to separate without severance the branches of the median nerve from those of the ulnar nerve It may then be extended up through the annular ligament at its ulnar edge and up the forearm, as shown. It crosses the flexion crease in the wrist in a curve so as to avoid resulting in flexion contracture. *B* Incision for draining thenar space. It parallels th thenar crease, must not sever the thenar motor nerve, and must leave pedicles sufficiently wide to nourish area of skin between it and incision for middl palmar space abscess. *C* Incision for part of thenar space dorsal to adductor muscles f thumb. It should be radial to the first interosseous muscle and stop short of cutting the radial artery as it passes through the first cleft. *D* Mid-lateral incisions in fingers and thumb which avoid volar nerves and vessels and do not produce flexion contractures. If made intermittently opposite the joints, the annular ligaments or pulleys which are opposite the centers of the phalanges will be pared. *E* Incision for draining pulp abscess. One should cut across lateral fat columns, be posterio to tactile surface, and not cause tenosynovitis by nicking the heath of the flex r tendon. *F* Flap incision for approach to extensor tendon in finger so that the incision will be remote from the tendon *G* Incision for approach to insertion of extensor tendon. *H* Palma approach to collar-button abscess to give open drainage. Avoid cutting nerve to finger *I* Dorsal approach to posterior part of collar-button abscess. It does not overl e the joint or tendon. *J*, Flap incision for subcutaneous abscess. One arm should be median t nerve, the other block the upward progress f the infection. *K* Incisions in forearm f r reaching tendons should parallel the fine wrinkling of the skin to be inconspicuous eventually and to avoid keloid formation. *L* Incisions for drainage of quadrilateral space in forearm. Entrance should be just anterior to bones and anterior to the radial nerve and posterior to the dorsal branch of the ulnar nerve.

of the radius, dissection is carried down to the interosseous membrane In order to do this, the portion of the supinator arising from the ulna is reflected subperiosteally The entire muscle mass, including the anconeus the upper portion of the extensor carpi ulnaris, and the supinator is then reflected radialward peeling the supinator from the upper fourth of the radius. This allows ample exposure of the lateral surface of the ulna and the upper fourth of the radius. The deep branch of the radial nerve which lies in the substance of the reflected supinator is protected, this point is clarified by reference to the cross sections in Fig 165 In the upper portion of the incision the recurrent interosseous artery is divided Exposure of the bones may be accomplished without division of the dorsal interosseous artery

This combined approach to the ulna and radius is especially useful in operative procedures on fractures of the upper third of the ulna associated with dislocation of the head of the radius. The approach may also be used in exposing the upper fourth of the radius alone with less danger of injury to the deep branch of the radial nerve than by other incisions

APPROACHES TO THE HAND AND FINGERS

Bunnell's illustrations (Figs. 166 and 167) of acceptable and pernicious incisions of the hand and fingers are with their accompanying captions, hereby reproduced and quoted These are classics of completeness and brevity

References

Abbott, L. C., and Carpenter W F Surgical Approaches to the Knee Joint, J Bone & Joint Surg 27 277 1945.

Bennett G E. Shoulder and Elbow lesions of Professional Baseball Pitcher J A. M. A. 117 510 1941

Bosworth, D M.: Posterior Approach to the Femur J Bone & Joint Surg 26 687, 1944

Bosworth, David M.: An Operation for Meniscectomy of the Knee J Bone & Joint Surg 19 1118 1937

Boyd, H. B: Surgical Exposure of the Ulna and Proximal Third of the Radius Through One Incision, Surg Gynec. & Obst. 71 86, 1940

Brackett, E. G., and Hall, C. L.: Osteochondritis Dissecans, Am. J Orth. Surg 15 79, 1917

Brackett, E. G., and Osgood, R. B: The Popliteal Incision for the Removal of Joint Mice in the Posterior Capsule of the Knee-Joint A Report of Cases, Boston M. & S. J 165 9 5 1911

Bunnell, Sterling Contractures of the Hand from Infections and Injuries, J Bone. & Joint Surg. 14 27 1932.

Burdick Quoted from Mayer Leo: J Bone & Joint Surg. 15 889 1933.

Campbell Willis C Incision for Exposure of the Elbow Joint, Am. J Surg 15 65, 1932.

Cave, Edwin F Combined Anterior Posterior Approach to the Knee Joint J Bone & Joint Surg. 17 427 1935

Coonse, K. D., and Adams J D A New Operative Approach to the Knee Joint Surg Gynec. & Obst. 77 344 1943

Cubbins, W R., Callahan J J., and Scuderi, C. S.: Fractures of the Neck of the Femur Open Operation and Pathologic Observations. New Incisions and New Director for Use of Simplified Flange Surg., Gynec. & Obst 68 87, 1939

Cubbins, Wm. R., Callahan James J and Scuderi, Carlo S The Reduction of Old or Irreducible Dislocations of the Shoulder Joint, Surg Gynec. Obst. 58 129 1934.

Eycleshymer A. C., and Shoemaker D M. A Cross-Section Anatomy, New York 1930 D Appleton & Co

Fisher A G Timbrell A New Method of Approach to the Semilunar Cartilages of the Knee-Joint Lancet 2 1407 1931

— Internal Derangement of the Knee-Joint, New York 1924 Macmillan Co., pp 60, 66 and 67

de Fresnelle Dupuy (Anterior U Iliofemoral Incision.) La voie d acces antérieure de l articulation de la hanche. Par chirurg 16 1 1924. (Quoted from Steindler: A Textbook of Operative Orthopedics, New York 1925 D Appleton & Co.)

Gaenslen F J Split Heel Approach in Osteomyelitis of Os Calcis, J Bone & Joint Surg 13 759 1931
Harmon, P H.: A Posterior Approach for Arthrodesis and Other Operations on the Shoulder, Surg., Gynec. & Obst. 81 266, 1945.
Henderson Melvin S.: Posterolateral Incision for the Removal of Loose Bodies from the Posterior Compartment of the Knee Joint Surg Gynec. Obst. 33 698 1921
Henry Arnold K.: Extensile Exposure Applied to Limb Surgery Edinburgh, 1945 E. & S. Livingstone.
Henry Arnold K. Exposures of Long Bones and Other Surgical Methods, Bristol 1927 John Wright and Sons, Ltd.
—: Exposure of the Humerus and Femoral Shaft, Brit. J Surg 12 84, 1924 25.
Hoffman Phil An Operation for Severe Grades of Contracted or Clawed Toes, Am. J Orth. Surg 9 441 1911 12
Jones, Sir Robert Disabilities of the Knee-Joint, Brit. M. J 2 169 1916.
Kaplan, E B.: Posterior Approach to the Superolateral Region of the Tibia, J Bone & Joint Surg. 28 805, 1946.
Kocher, Theodor Textbook of Operative Surgery London 1911, A. & C. Black, Ltd.
Koenig F., and Schaefer P Osteoplastic Surgical Exposure of the Ankle Joint. Forty First Report of Progress in Orth. Surg., p 17 (Abstracted from Ztschr f. Chir 215 196 1929)
MacAusland, W R., and MacAusland, A R.: The Mobilization of Ankylosed Joints by Arthroplasty, Philadelphia 1929 Lea & Febiger pp. 64 and 171
McLaughlin, H. L.: Lesions of the Musculotendinous Cuff of the Shoulder I. The Exposure and Treatment of Tears With Retraction, J Bone & Joint Surg 26 31 1944.
McWhorter G L.: Fracture of the Greater Tuberosity of the Humerus With Displacement; Report of Two Operated Cases With Author's Technic of Shoulder Incision, S. Clin. North America 5 1005 1925.
McWhorter G L. Old Posterior Dislocation of the Shoulder With Complete Disability Reduction by the Author's Posterior Shoulder Incision Technic of Applying Shoulder Spica S. Clin. North America 12 1239 1932.
Molesworth, W H. L. Operation for Complete Exposure of the Elbow Joint, Brit J Surg. 18 303 1930
Ober Frank R. Posterior Arthrotomy of the Hip Joint, J A. M. A. 83 1500 1924.
Ollier P Traité des Résections, Paris, 1892. (Quoted from Steindler Arthur: A Textbook of Operative Orthopedics, New York, 1925 D. Appleton & Co.)
Osborne, R. P The Approach to the Hip-Joint A Critical Review and a Suggested New Route, Brit. J Surg 18 49 1930-31
Roberts, S. M. Acromioclavicular Dislocation, Am. J Surg 23 322, 1934
Rowe C. R. and Yee, L. B K.: A Posterior Approach to the Shoulder Joint J Bone & Joint Surg. 26 580 1944.
Smith Petersen, M. N A New Supra Articular Subperiosteal Approach to the Hip Joint Am. J Orth. Surg 15 592 1917
Sutherland, R., and Rowe, M. J., Jr: Arthrotomy Approaches in the Lower Extremity Am. J Surg 71 335, 1946.
Sutherland, R., and Rowe M. J Jr Simplified Surgical Approach to the Hip, Arch. Surg 48: 144 1944.
Thompson James E. Anatomical Methods of Approach in Operations on the Long Bones of the Extremities, Ann. Surg 68 309 1918.
Van Gorder G W: Surgical Approach in Supracondylar T Fractures of the Humerus Requiring Open Reduction, J Bone & Joint Surg 22 278, 1940
Wagoner George A Technique for Lessening Hemorrhage in Operations on the Spine J Bone & Joint Surg 19 469, 1937
Watson-Jones, R. Fractures of the Neck of the Femur Brit. J Surg 23 787, 1935-36.
Wilson, Philip D: Complete Rupture of the Supraspinatus Tendon J A. M. A. 96 433, 1931

CHAPTER V

ACUTE INFECTIOUS (PYOGENIC) ARTHRITIS
WOUNDS OF JOINTS

Acute infectious arthritis is one of the common destructive lesions affecting the joints. The infectious organisms may be conveyed to the joints by the blood stream from distant foci, may be introduced directly through wounds or lacerations, or may extend from an adjacent osteomyelitis. In the majority of cases, the disease is monarticular or confined to one joint In the multiple infections, the process is generally acute in one or more joints and subacute or mild in others. Cultures of the exudate should be made in every case to determine the causative agent, this may be any one of the ordinary pyogenic bacteria such as staphylococcus, streptococcus, gonococcus, or pneumococcus. The subsequent section deals primarily with lesions of hematogenous origin Wounds of joints are discussed separately

Clinically the disease is often classified according to the infectious agent The pathologic process, symptoms and physical signs are so similar however regardless of the organism present or the mode of infection that the same general principles of treatment are applicable to every type.

Acute infectious arthritis may be divided into three stages (1) acute, (2) subacute, and (3) residual In the *acute stage* the object of treatment is arrest of the infection by conservative measures, alone or combined with surgical drainage Seriously ill patients should be treated systemically as outlined in the chapter on Preoperative and Postoperative care This treatment consists briefly of maintenance of a proper fluid balance, relief of pain by adequate sedation, the administration of transfusions and finally chemotherapy and antibiotic therapy

Conservative local treatment consists of aspiration and immobilization of the joint and the instillation of antibiotics. Aspiration, which is the process of removing fluid from the joint, is employed for several reasons (1) to decrease tension in the joint and relieve pain, (2) to permit one to determine the nature of the fluid and the type of the organism (3) for the purpose of irrigation (4) for instillation of a therapeutic agent, and (5) to act as a temporary evacuant of purulent material from the joint. The procedure is carried out with observance of rigid rules of asepsis, as though it were a clean joint. The skin surfaces should be thoroughly prepared and draped before the needle is introduced.

Aspiration every 24 to 48 hours, supplemented by the introduction of an antibiotic agent into the joint frequently obviates the necessity for incision and drainage In addition it may prevent considerable damage to the joint structures until the chemotherapeutic agent has reduced the toxicity of the organism and fluid within the joint no longer causes tension. Key notes that, by parenteral and local administration of chemotherapeutic agents, many joints may be saved and function promptly restored. He suggests that large amounts

of penicillin be injected directly into the joint, the penicillin being combined with a sufficient amount of saline to distend the joint cavity slightly The aspiration and injection of penicillin is repeated daily until the disease has subsided, or the indication for surgical intervention is presented

Rest is one of the first principles of treatment of an inflammatory lesion thus, immobilization plays an important part in allaying and combating the infection, as well as in the relief of pain. In the proximal joints, such as the knee and hip immobilization is preferably carried out by means of traction. This not only provides adequate immobilization, but also assists in relieving muscle spasm and correcting or preventing contracture Subsequent examinations or dressings of the joint moreover are carried out with comparative ease, whereas a splint or cast adds to the difficulty

The continuous use of hot wet packs is probably of little value in combating infections or stimulating defensive mechanisms which are already active The packs, however seem to afford some relief of pain and the dressing if sufficiently bulky provides further immobilization of the inflamed and tender joint.

Since anatomy does not change, the approaches for incision and drainage of the joints have remained essentially unchanged from year to year The indications for the use of these approaches, however have altered materially since the introduction of chemotherapeutic and antibiotic agents. Now one may safely and properly be more conservative. The factors which must be taken into consideration prior to incision and drainage are the origin of the infection the type of organism the location of the lesion the intensity of the infection and finally the response to the conservative measures outlined above

Arthritis induced by organisms from without is often more difficult of management than infections of hematogenous origin. The prognosis, also is less favorable The disease process may not be localized to the articulation rather it may have spread from the original wound to the fascial planes, giving rise to diffuse cellulitis or abscess Following any subsequent surgical or manipulative procedure, exacerbations of the infection are more likely as is also scar contracture and consequent impairment of function. Several strains of the same bacterial organism or numerous types of pathogens may be present. Gas-forming bacilli may complicate the infection.

Among the ordinary pathogenic organisms the staphylococcus seems to be most resistant to chemotherapeutic and antibiotic agents, as well as to other conservative measures. In proved staphylococcic infections with a frank, purulent exudate, drainage is indicated earlier than for other infections. It should not be delayed until the cartilaginous surfaces have been absorbed, and this may be only a matter of days.

Under conservative treatment moderately or mildly virulent infections of the deep-seated joints, such as the spine and hip may heal oftener than more superficial ones, without abscess formation and draining sinuses. Unless osteomyelitis is associated, operative measures on joints of the fingers and toes are seldom required.

In the last analysis, the intensity of the infection, as determined by the constitutional and local symptoms, the character of the joint fluid, and the response

to conservative treatment, should be the criteria for incision and drainage. As an emergency procedure incision and drainage of a joint is a thing of the past other than under the most extraordinary circumstances. Although virulent, if the infection is observed from its incipiency, one is justified in waiting several days to observe the effects of conservative treatment. Under no circumstances should a gonorrheal joint be drained and many streptococcic and even staphylococcic infections may now be treated successfully by conservative means. Incision and drainage are indicated only in the presence of severe constitutional and local symptoms. Even though soft tissue abscesses may have formed a twenty four hour period of preparation should be enforced to allow for improving the patient's general condition and establishing an adequate level of a chemotherapeutic or antibiotic agent in the blood.

Whether the infection is arrested by conservative measures, or by surgical drainage, apparatus should be applied to maintain the joint in the position which will permit maximum function in the event of ankylosis. Active motion of the joint during the acute stage is not permissible, yet active contracture of the muscles assists in maintaining the tone of the extremity.

In the *subacute stage* the process is one of resolution and organization. If surgery has been necessary, adequate drainage is continued. As the symptoms subside, treatment should be directed toward the prevention of deformity and re-establishment of function. Acutely inflamed joints are not fit subjects for either active or passive exercise, as this only exacerbates the infection and delays healing. On the contrary, to wait until adhesions are well formed, or ankylosis is established is also an error. The time to begin passive and active motion is between these two extremes. There are no definite criteria for determining just when this time arrives, each patient is an individual problem. In general, however, the constitutional manifestations of the disease, especially fever, should have been quiescent for three to five days, and the local reaction from the inflammatory lesion should have subsided. Passive motion must be given without inducing a local reaction. As a rule, the patient will not voluntarily move the joint with sufficient violence to incite a severe reaction. In the intervals between exercises, the joint is immobilized in the optimum position until a satisfactory range of strong active motion has been acquired. The services of a well trained physical therapist who is capable of understanding the physical and mental status of the patient and can follow instructions explicitly are desirable.

In weight bearing joints, ankylosis in the most advantageous position is preferable to a few degrees of painful motion, particularly if the patient is a laborer. Virulent infections with extensive destruction of the joint surfaces may be permanently crippling. If this outcome seems inevitable *efforts to* mobilize the joint should be abandoned in favor of continued immobilization thereby promoting ankylosis.

Except in the hip joint, osteomyelitis is ordinarily only superficial sequestration of bone is rare. For this reason operative measures are confined to the articulation. When the joint is invaded by infection from an adjacent bone or vice versa, the treatment should be that employed for osteomyelitis (Chapter XVIII).

In late cases where previous conservative treatment or surgery has failed to eradicate the infectious process, wide incision and drainage may be indicated In some instances, resection and fusion, or even amputation may be warranted.

Neglected or improperly treated patients frequently are first observed during the subacute stage with varying degrees of deformity Forceful correction of deformity or brisement forcé, is contraindicated, as the pyogenic infection may be relighted and become more virulent, causing increased destruction More conservative measures, described in Chapter II accomplish the desired result with less likelihood of unpleasant complications.

The residual stage is characterized by complete subsidence of the infection and partial or complete limitation of motion. When subsequent operations are undertaken one must bear in mind the possibility of reactivating a dormant infection Treatment should consist of surgical correction of the deformity and measures to restore a useful range of motion (see chapters on Ankylosis and Deformity, and Arthroplasty)

OPERATIVE MEASURES IN ACUTE STAGE

TARSAL JOINTS

Drainage

Technic.—An uncontrolled infection in the tarsal joints calls for liberal drainage. A lateral or medial incision, depending upon the joint affected is made for a distance of two or three inches parallel with the long axis of the foot The superficial and deep fasciae are divided, the capsule is opened wide and the purulent material evacuated. A specimen of the contents should be taken and cultures made and examined to identify the infective microorganism Petrolatum gauze is inserted down to but not within, the joint cavity

After Treatment.—The foot is supported at a right angle to the leg and the tarsal joints are immobilized in a posterior splint or cast Continuous dressings saturated with warm boric acid or other mildly antiseptic solutions may be applied. If immobilization is effected by a plaster of Paris cast, the vaseline gauze may be allowed to remain in situ, according to Orr s method of treating osteomyelitis. Complete healing of the wound may be expected within three to six months. During this time, dorsal contraction of the toes, from an associated tenosynovitis, must be prevented by frequent active plantar and dorsal flexion, or by the application of a splint to hold the toes in plantar flexion Not until all evidence of acute infection has subsided and the wound is healing is walking permitted

After any acute inflammatory process there is usually a decrease in tensile strength of the ligaments and fasciae, as well as an extensive osteoporosis of the bony structures from loss of calcium salts, as indicated by the decrease in density of the bones observed in the roentgenogram. Further destruction may have produced a loss in continuity of the bone Unsupported weight bearing may cause overstretching of the ligaments or compression of the softened bone or both with a resultant flattened arch. This eventuality may be avoided when walking is instituted by having an efficient support fitted to the longitudinal and anterior metatarsal arches (p 128) When the roent

genogram shows that the structure of the bone is approximately normal which generally requires from three to six months, the arch support may be discarded

ANKLE

Aspiration

Fluctuation about the ankle joint is often imperceptible on account of swelling of the periarticular tissues Obliteration of the malleoli and other bony prominences, incident to swelling also contributes to the difficulties of aspiration A sympathetic effusion into the tendon sheaths, which is often associated with suppurative arthritis, may be responsible in some measure for the swelling A suppurative tenosynovitis should not be confused with purulent arthritis.

To avoid injury to important structures, the needle should be inserted on the anterolateral aspect of the joint approximately one inch above and one half inch medial to the external malleolus

Drainage

Drainage of the ankle joint may be effected through any one of five different incisions, as follows anterolateral, posterolateral, anteromedial, posteromedial and anteromedian.

Anterolateral Incision—Technic.—The skin over the joint is incised for a distance of two or three inches at a site one half to one inch medial to the external malleolus. Dissection is carried through the fascia just lateral to the sheath of the extensor tendons, thence into the capsule of the joint.

Posterolateral Incision—Technic (David).—According to David the posterolateral approach has been proved experimentally to be safer and more effective than any other

The foot should be dorsiflexed as this position tends to obliterate the anterior compartment and correspondingly to enlarge the posterior compartment, permitting more thorough evacuation of the purulent material. The incision begins two inches above the external malleolus and just lateral to the tendo achillis, extends down to the os calcis, and follows its superior border for a distance of one inch The external saphenous nerve and vein are retracted posteriorly The thick pad of fat encountered over the posterior ligament is pressed downward against the entrance to the subastragalar joint for protection. The flexor hallucis longus tendon is retracted medially and the joint is entered above the shining cord like posterior fasciculus of the external lateral ligament Care must be taken to open the posterior capsule under direct vision.

This incision likewise affords an excellent approach for drainage of the subastragalar joint

Anteromedial Incision—Technic.—An incision three inches in length is made on the anterior aspect of the ankle along the medial border of the tibialis anticus tendon and carried directly into the capsule of the joint *The tendon sheaths should not be disturbed.*

Posteromedial Incision—Technic.—When the infection is severe, posterior medial drainage may be effected through an incision three or four inches in

length medial to and parallel with the tendo achillis. This exposes a mass of adipose tissue covering the posterior capsule. The flexor hallucis longus tendon, which traverses the posterior capsule of the joint from above downward and inward, must be retracted medially before the capsule is incised. The tibial nerve, posterior tibial vessels, and the tendons which lie on the posterior aspect of the internal malleolus should be avoided.

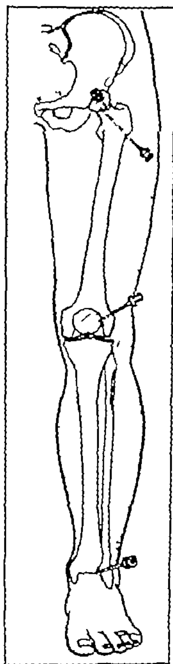


Fig. 146.—Aspiration of ankle, knee, and hip joints.

Anteromedian Incision—Technic.—An incision in the midline anteriorly is employed to drain the anterior compartment of the joint. This approach is advisable only when an acute pyogenic infection is complicated by an infection of the tendon sheaths. Even so the procedure is not recommended, as the extensor tendons, deep peroneal nerve and dorsalis pedis artery must be dissected out and retracted in order to expose the anterior capsule.

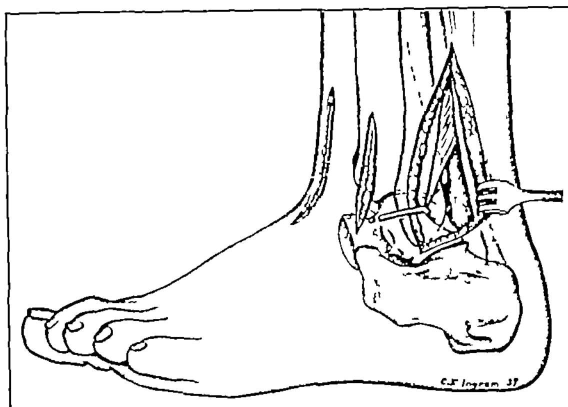


Fig 169.—Posterolateral anterolateral, and anteromedian incisions for drainage of ankle.

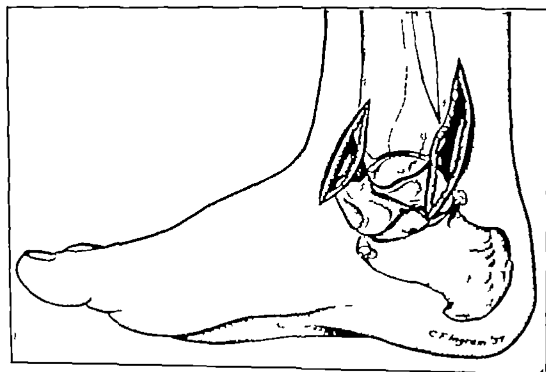


Fig. 170.—Posteromedial and anteromedial incisions for drainage of ankle.

Following incision of the capsule by any of the foregoing technics, drainage should be maintained by the insertion of vaseline gauze or a small rubber tube down to but not within the joint

After Treatment.—The prevention of equinus deformity should be a part of any treatment for infections of the ankle. Since the foot falls by gravity into equinus the tendo achillis and posterior capsule of the joint rapidly become contracted. A simple splint which holds the foot at a right angle to the leg will preclude this development

Active and passive motion are instituted in the ankle immediately following subsidence of acute symptoms apparatus devised especially for this purpose facilitates movement. When walking is permitted a brace, so constructed as to support and limit ankle joint motion (Fig 17) is recommended until a sufficient degree of painless voluntary motion is recovered Deformity may be corrected during the subacute or residual stages by apparatus which gradually flexes the foot in the dorsal position. If the foot is fixed in equinus however surgical correction is indicated in the residual stage

KNEE

Aspiration

The knee, being a superficial joint, may be aspirated with comparatively little difficulty The needle is inserted at the level of the upper extremity of the patella on the outer side of the joint (See Fig 168)

Drainage

Unless the posterior compartment is distended and a popliteal or posterior abscess is well established, parallel anterior incisons combined with Henderson incisions are usually the procedure of choice. If possible, posterior drainage should be avoided, as the infection may extend through the fascial planes of the thigh and leg

Anterior Incision—Technic.—The skin is incised for a distance of three or four inches on both the inner and outer aspects, sufficiently medial and lateral to each side of the patella and patellar ligament to prevent pocketing The structures encountered are the superficial and deep fasciae, the capsule and synovium. The deep fascia is well developed and should not be mistaken for the true capsule The synovial membrane is stitched to the skin with plain catgut, to prevent cellulitis between the fascial planes. A petrolatum gauze drain is inserted down to but not within, the joint. In the majority of cases, this is sufficient to promote healing within two to four months.

Persistence of symptoms, or a palpable fluctuation posteriorly indicates a pocket in the posterior compartment of the joint. Posteriorly the knee may be divided by a median septum into medial and lateral compartment. Either or both of these will require drainage, which may be accomplished by the Henderson or the Osgood, Brackett, Putti technic.

Lateral Incision—Technic (Henderson).—With the knee in flexion, a three inch incision is made on the lateral aspect of the knee just anterior to the head of the fibula and biceps tendon This approach avoids the common

peroneal nerve which parallels the posteromedial border of the biceps tendon and passes around the head of the fibula The incision is continued through the iliotibial band to the bone thence by subperiosteal dissection into the posterior compartment

Medial Incision—The skin is incised anterior to the relaxed tendons of the semimembranosus, semitendinosus, sartorius, and gracilis muscles (Fig 122) Dissection is carried down to the bone and subperiosteally into the posterior compartment

Posterior Midline Incision—Technic (Osgood, Brackett, Putti)—A posterior linear incision ten centimeters long is made over the popliteal space, centering over the joint line, and slightly medial to the midline The tibial nerve is practically superimposed upon the popliteal vessels in the center of the popliteal space, these structures are identified and retracted outward The posterior ligament and capsule of the knee are exposed by blunt dissection and incised transversely

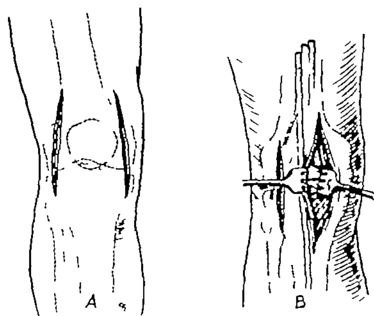


Fig 171—*A* Parallel incisions on each side of patella for anterior drainage of knee. *B* Parallel posterior incision for drainage of posterior compartment of joint.

Posterior Lateral and Medial Incisions—Technic—The popliteal space is approached laterally by an incision three inches in length through the skin and deep fascia. The peroneal nerve and biceps femoris tendon are identified and retracted laterally and the popliteal vessels and tibial nerve which are in the midline are retracted medially By blunt dissection, the lateral head of the gastocnemius and the popliteus muscles are defined on the outer side A transverse incision is then made over the external condyles of the femur into the lateral portion of the posterior capsule

A second incision of the same length is made on the medial side of the popliteal space, parallel and just lateral to the medial hamstring muscles. These muscles are retracted inward and the popliteal vessels and tibial nerve are retracted to the outer side The medial head of the gastrocnemius is exposed a transverse incision is made over the internal condyle of the femur

and the medial portion of the posterior capsule is incised Drainage is ma tained by lining the wounds with petrolatum gauze.

Although dependent drainage is established by this procedure inf tion may be carried down between the gastrocnemius and soleus muscles, le ing to the formation of deep-seated abscesses which will require furtl drainage

Irrigation

In subacute or mild infections of joints, particularly the knee, irrigat may serve as a satisfactory adjunct to other conservative forms of treatme In the light of present knowledge, the Cotton technic should be supplemen by the introduction of a chemotherapeutic agent into the joint after the irri tion is complete

Technic (Cotton) —*Under local anesthesia, a small trocar or cannula* inserted on each side of the joint. Through a tube attached to a douche c from three to five gallons of normal saline solution are introduced into the fected area. This is repeated on alternate days until constitutional sympto have subsided.

After Treatment.—Following drainage or irrigation, the joint must held in extension by some type of traction. Buck's extension is most co fortable and usually is efficient. When the acute symptoms subside, pass and active motion should be instituted and practiced every three hours, l ginning cautiously For this purpose, a Thomas splint with a joint at the kr may be fitted (Fig 60) The patient is taught first, voluntary movement the patella by contraction of the quadriceps muscle on the normal side a then to apply this to the affected extremity Active movement of the l may be accomplished with the patient lying on the normal side and on t abdomen as this position removes the force of gravity from quadrice action. Special exercises should be practiced to restore the quadriceps mus to normal power as rapidly as possible, regardless of the causative organis When walking is permitted, a control dial or drop ring catch knee bra (Fig 20) should be applied that the range of motion may be gradually : creased. Even after a fair range of active motion has been established, the is a tendency toward flexion deformity this may be overcome by the use a long night splint for several months after the symptoms subside An a paratus constructed on the same principles as the hinge Thomas spli (p 76) will enable the patient to carry out systematic exercises. The nig splint and brace are not discarded until a satisfactory range of active m tion is restored particularly as to extension.

Function cannot be coerced, but must be induced slowly otherwise, the will be a reaction which may cause an exacerbation of the infection and d feat the purpose of the treatment.

Incision, Irrigation, and Closure

Cotton, H. T Jones, and others have advised *irrigation and cleaning of t* joint under direct vision through a surgical exposure of the joint. By th technic, fibrin, devitalized tissue, and other debris may be removed more tho oughly than by aspiration and irrigation This procedure is particularly a plicable to sepsis secondary to wounds (p 220)

HIP

Treatment of pyogenic infections of the hip in children and adults is somewhat dissimilar because of the difference in anatomy and physiology of the joint The capsule of the hip joint encircles a large portion of the neck of the femur, which is invested only by synovial membrane Since no real periosteum is present the infection often extends from the joint directly into the adjacent bone In children extension is more likely, as the capsular and epiphyseal arteries pass through the infected region before reaching the neck and epiphysis. During the period of active epiphyseal growth, the arterial circulation in the metaphysis is commensurately active and extensive invasion of the epiphysis and osseous neck is the usual course except in very mild or attenuated infections. In fact the infection probably begins in the epiphysis, in many instances, and is carried into the joint For these reasons, drainage may be necessary in infants and children The tissues of adults are more resistant and osteomyelitis of the neck is a less common complication In most cases, therefore conservative measures are adequate

Bilateral pyogenic infection is observed in the hip more often than in any other joint and not infrequently is associated with infection in the spine The treatment of multiple infections should be conducted upon the principles employed for single lesions the problem however is far more difficult and the disability much greater

Aspiration

For aspiration of the hip joint the lateral posterior or anterior approach is suitable.

In the lateral approach the needle is inserted just below and anterior to the greater trochanter forming an angle of 45 degrees with the surface of the thigh To prevent forward angulation, the needle should closely approximate the bone in passing inward and upward into the joint—a distance of two to four inches, according to the size of the patient The needle should not be allowed to pierce the articular surfaces, as this might instigate infection of the head of the femur or pelvic bone

To aspirate posteriorly the needle is inserted at the juncture of the outer and middle thirds of a line drawn from the center of the trochanter to the posterior inferior spine of the ilium

Aspiration is accomplished anteriorly by insertion of the needle perpendicularly to the skin at a point one inch below and one inch lateral to the center of Poupart s ligament Usually the femoral artery is at the center of this ligament and may be used as a guide in determining the point of entrance of the needle (see Fig 168)

If the diagnosis cannot be confirmed by aspiration as happens occasionally when the joint contains a small amount of fluid or extremely purulent material exploration is indicated if local and constitutional symptoms are uncontrolled by conservative treatment.

Drainage

Drainage of the hip is best carried out by the posterior incision of Ober although the anterior lateral, and medial approaches may also be employed. Occasionally the infection invades the soft tissues producing a fluctuant

abscess, which may point posteriorly laterally anteriorly or in the adductor region Anterior or adductor abscesses may develop following infection direct from the hip joint or from an associated pelvic abscess. In any event, both the Ober incision and an anterior, lateral, or medial approach may be necessary in order to effect thorough evacuation of the hip joint and associated soft tissue abscesses.

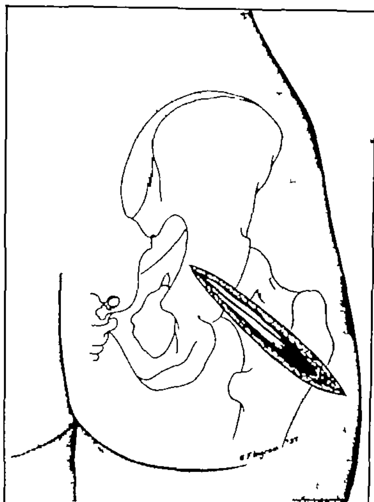


Fig. 172.—Ober posterior incision for drainage of hip joint. Line of skin incision.

Posterior Incision—Technic (Ober) —An incision is made in line with the neck of the femur beginning on the posterolateral aspect of the greater trochanter thence extended upward and medially toward the posterior superior spine, and the gluteus maximus muscle is divided in line with the incision. The branches of the gluteal artery should be clamped as exposed, to prevent their retraction and embarrassing hemorrhage Division of the muscle fibers reveals a layer of fat by gentle blunt dissection the sciatic nerve should be located in this fat in the medial angle of the incision and protected from injury The obturator internus, quadratus femoris, inferior and superior gemelli, and the pyriformis muscles, which lie beneath the fatty layer are divided parallel to the neck of the femur also by blunt dissection. If a larger operative field is desired these muscles may be freed at their attachments to the trochanter The capsule, which is easily recognized when distended with fluid,

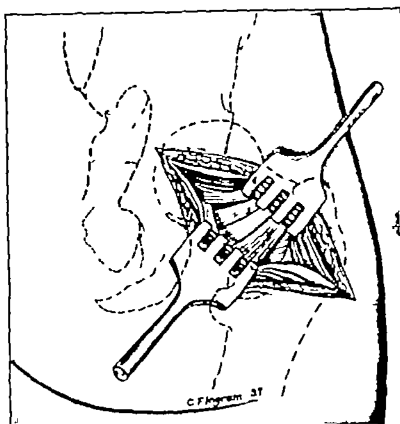


Fig. 173.—Same as in Fig. 172. Fibers of gluteus maximus separated, revealing gemelli, pyriformis, and obturator internus muscles. Sciatic nerve exposed in upper end of incision.

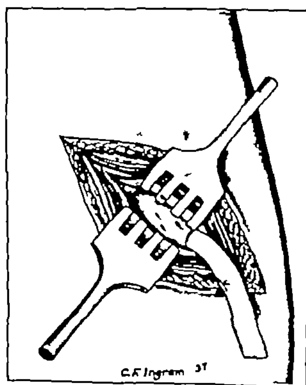


Fig. 174.—Same as in Fig. 172 after incision of capsule. Complete exposure of posterior aspect of hip joint. Rubber tube drain inserted down to but not within joint.

is split throughout its length, thus exposing the acetabulum and neck. If necessary, the capsule may also be incised in a transverse direction. Two cigaret drains are sutured to the lateral portion of the capsule. Being posterior and dependent, they drag the capsule into funnel shape, which promotes rapid drainage. If one prefers, the capsule may be sutured to the gluteal fascia; in this event, the drains are not used. Since drainage is established at the most dependent point, rarely is an additional incision required.

Anterior Incision—Technic.—A longitudinal incision three to four inches in length is made just below the anterior superior spine of the ilium and passed through the superficial and deep fasciae, exposing the sartorius muscle on the inner side and the tensor fasciae femoris and vastus lateralis muscles on the outer side. These structures are separated by blunt dissection down to the capsule of the joint. Should a wider view be required, the incision may be extended upward, separating the attachments of the tensor fasciae femoris, gluteus minimus, and gluteus medius muscles from the crest of the ilium subperiosteally after the manner of Smith Petersen and Sprengel. The lateral femoral cutaneous nerve in the upper extremity of the wound should be avoided, if possible. Also care should be taken to protect the branches of the lateral femoral circumflex artery which pass into the vastus lateralis muscle, although no apparent harm results from ligature of these vessels.

Following incision of the capsule a rubber tube, Dakin's tube or vaseline wick should be inserted for drainage. The extremities of the wound may be closed with silkworm gut suture.

Lateral Incision—Technic.—A longitudinal incision three to five inches in length, depending upon the patient's size, is made parallel to the anterior border of the greater trochanter. The superficial and deep fasciae and fascia lata are incised, exposing the fibrous investment of the vastus lateralis muscle. The latter is detached, thereby exposing the anterior surface of the trochanter. Following the anterior aspect of the neck of the femur, the bone and periosteum are separated to the capsule of the joint. The capsule is opened and, if necessary, spread wide with a large hemostat. Drainage is established and maintained by a rubber tube.

Medial Incision—Technic (Ludloff).—A three-inch longitudinal incision is made on the medial aspect, exposing the upper one-fourth of the gracilis and adductor longus muscles. The line of cleavage between the adductor longus and adductor brevis muscles is defined. Blunt dissection is carried posterior to the adductor longus and pectineus muscles into the abscess cavity, which is connected directly with the hip joint behind the iliopsoas muscle. To maintain drainage, a rubber tube is inserted behind the iliopsoas muscle adjacent to the joint. Supplementary drainage by the Ober technic may be required for the infection within the joint.

After Treatment.—The patient is placed on either a Bradford frame or a mattress supported by boards. Adhesive strips are applied from just below the hip to the ankle, and traction is instituted by Buck's extension, with five to ten pounds of weight to the extremity. A Thomas splint, also, is a convenient form of immobilization.

In certain cases, particularly if there is an associated severe osteomyelitis

as for Buck's extension and the patient is placed in a plaster of Paris cast from the ankle to the nipple line Traction is carried out by weights attached to the ends of the adhesive protruding from the end of the cast. The Hoke-Martin apparatus (p 48) is particularly useful The joint should be immobilized in the most serviceable position for future function which is 160 degrees *abduction* and neutral extension and rotation



Fig. 176.—Minimum arthritic changes slight narrowing of joint space, and moderate incongruity of head of femur twenty-one years after pathologic dislocation of hip This represents the best that can be expected, and is relatively uncommon. End results are more likely to be less favorable than in this patient, yet more favorable than those illustrated in Fig 177

As soon as the acute symptoms have entirely subsided roentgenograms should be made to determine the contour of the joint. If this is found to be relatively normal, passive and active motion are instituted by means of overhead pulleys (Fig 62) To maintain the elective position, the use of apparatus is continued until a satisfactory range of voluntary control is restored. If the bone is only mildly affected, healing may take place within a few weeks, with a good functional result. If destruction is extensive, the use of apparatus must be continued for one to two years in children and for six months to one year in adults, until there is solid osseous ankylosis

In children with advanced osseous destruction, some degree of abduction and flexion deformity may develop after the apparatus has been discarded. The younger the child the greater the likelihood of deformity This is a



Fig. 176.—Pathologic dislocation of hip. *A* Hip joint injected with air showing distention and stretching of capsule. *B* After reduction drainage of hip by Ober technic.



Fig. 177.—Pathologic dislocation of hip *A* Beginning sequestration of head, as evidenced by increased density *B* Sixteen months later Head and portion of neck have been completely absorbed.

natural evolutionary process which must be anticipated As a consequence correction by subtrochanteric osteotomy (Chapter XVI) may be required later and the parents should be so informed

Complications of Acute Infectious Arthritis of the Hip

Pathologic Dislocation.—This occurs only in children If the dislocation is of recent occurrence and is recognized before extensive organic changes have taken place, reduction may be effected without difficulty when the joint is drained. In some cases, normal function may be thus restored

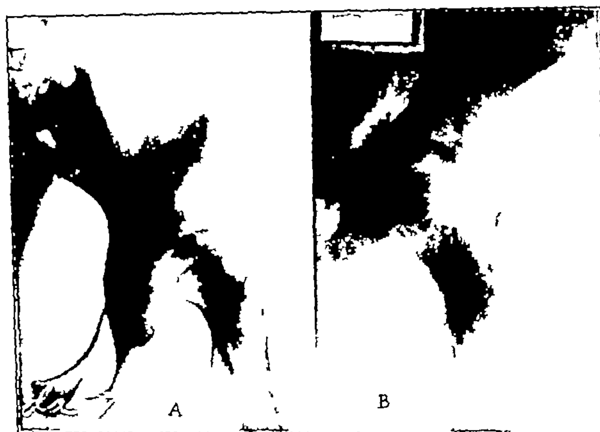


Fig 178.—*A*, Acute infectious arthritis and pathologic dislocation of hip, secondary to osteomyelitis of ilium. *B* Reduction accomplished without difficulty after drainage by Ober technic.

When the head of the bone has been widely invaded by the destructive process following a dislocation of the hip forceful reduction should not be attempted as this will cause crushing or fracture of the bone. Rather, skeletal traction should be applied to the lower extremity of the femur until the head of the bone approximates the acetabulum Reduction is then effected by abduction and rotation of the leg and a cast is applied which holds the extremity in the position for optimum function. To prevent adduction deformity fixation is maintained by a cast or brace until the hip is stable or solid ankylosis has occurred. After extensive destruction osseous ankylosis is desirable

Osteomyelitis—If infection is confined primarily to the hip early and adequate drainage may be indicated. This offers an opportunity to prevent osteomyelitis of the neck or if the osteomyelitis is primary it may relieve some of the processes of repair and prevent sequestration of the epiphysis. If se

questration occurs and the patient is under twelve years of age the sequestrated disc may be replaced by new bone, since circulation is restored through the attachment of the capsule near the inferior portion of the epiphysis, or the disc may be completely absorbed rarely does it remain as an infected sequestrum. After the age of twelve to fourteen years, the disc contains a large proportion of bone and may remain as an infected sequestrum requiring operative removal. This may be accomplished by any of the incisions employed for drainage, although the anterior incision is preferable in that better exposure is provided. If the infection has not been severe and the response to chemotherapy has been favorable one may close the anterior incision and dispense with drainage Otherwise, through and through drainage is established by an additional Ober incision and the limb is fixed in the most serviceable position

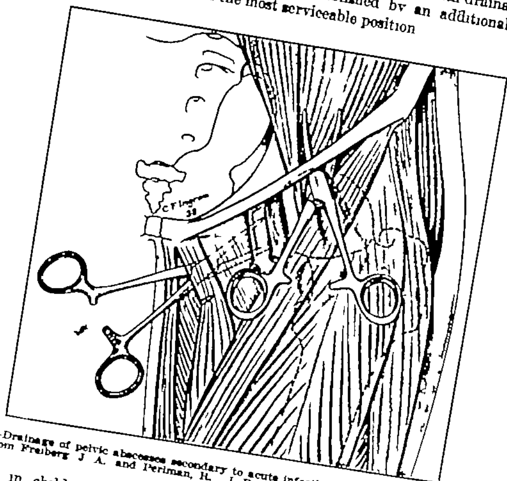


Fig 179—Drainage of pelvic abscesses secondary to acute infectious arthritis of hip. (Redrawn from Freiberg J A. and Perlman, R. J Bone & Joint Surg. 18: 417 1936.)

Also in children there may be an extensive osteomyelitis of the il
secondary to infection of the hip joint or the infection of the hip may a
from osteomyelitis of the ilium. In such cases drainage of both the hip joint a
the ilium is necessary In adults, an associated osteomyelitis of the ilium is
much less common complication however interference with circulation to t
head of the femur may lead to pathologic fracture of the neck with sequestratio
of the head.

Pelvic Abscess.—Pelvic abscess associated with acute infectious arthritis of the hip joint develops as a result of a suppurative lymphadenitis of the lymph glands which drain the hip joint and lie adjacent to the course of the external iliac artery The abscess lies retroperitoneally and tends to gravitate

along the course of the iliopsoas muscle to Poupart's ligament, pointing subcutaneously over the pectineus muscle or between the adductor longus and adductor brevis muscles. If unusually large, the iliac abscess may gravitate upward along the iliopsoas sheath and present as a fluctuating mass above the posterior crest of the ilium

Joseph Freiberg advocates drainage by the following procedures If there is definite fluctuation in the adductor region a longitudinal incision is made on the inner aspect of the thigh between the adductor longus and gracilis muscles (Ludloff) By blunt dissection between the adductor longus and adductor brevis muscles, the abscess is located either behind or in front of the pectineus muscle. If the mass presents subcutaneously over the pectineus muscle, the incision may be made at this site. Since this area contains many large vessels, hemorrhage may be somewhat extensive

Drainage should not be attempted above Poupart's ligament as thorough evacuation is impossible further a fecal fistula may be induced.

In the presence of an unusually large iliac abscess the adductor drainage may be supplemented by a three-inch oblique incision beginning one inch above and parallel to the posterior crest of the ilium lateral to the erector spinae muscles. The incision is carried through the insertion of the obliquus internus abdominis muscle, and then by blunt dissection directly into the abscess. Adequate drainage is maintained by a rubber tube drain. The associated pyogenic infection of the hip is treated by the posterior technic of Ober

Persistent Infection.—Persistent deep-seated infection in and about the hip joint with recurrent exacerbations and all the local and general effects of a chronic sepsis, presents a difficult therapeutic problem. Fortunately, with the use of chemotherapy fewer cases may be expected in the future.

As a rule, fairly extensive drainage incisions have been made, followed by the establishment of draining sinuses. Frequently the sinuses have become blocked, giving rise to severe systemic reactions. Further drainage is then required, yet seems to be inadequate Unless a more radical procedure is performed, some of these patients will die of chronic sepsis and amyloid degeneration of the viscera. This is particularly true of those having a secondarily infected tuberculous hip (Chapter XIV)

Girdlestone briefly described a radical resection of the hip joint for the foregoing type of case and, in 1941 he described the procedure in detail as applied to pyogenic infections about this joint. His technic is unusual in that the approach is made through an incision transverse to the muscle plane Further in addition to all the infected bone a sufficient mass of muscle tissue is resected to insure adequate drainage over a long period of time, i e virtually *a complete* saucerization of the infected area in and about the hip joint is carried out. Girdlestone recommends this procedure for any pyogenic *infection* of the hip whether hematogenous in origin or incident to a compound fracture, if sepsis and fever have not responded to conservative measures. He *believes that* in the presence of a persistent infection an extremely radical operation, such as the one described, is necessary in order to insure *drainage*. With this, we can not agree it is our opinion that an ordinary pyogenic *infection of the hip* will respond to conservative treatment or to more moderate surgery He mentions the type of case however in which a procedure of this magnitude might be in

dicated that wherein the infection has deeply and extensively involved the muscle planes as well as the acetabulum and ilium, though the joint itself may or may not be ankylosed Septic necrosis of the head of the femur may further complicate the picture, perhaps with intrapelvic abscesses or abscesses in the adductor region He advises that, prior to operation any deep-seated abscesses

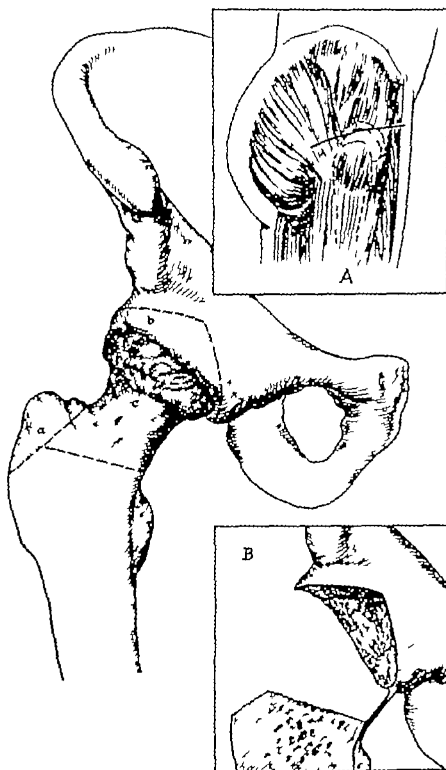


Fig. 180—Girdlestone resection of hip for chronic or persistent deep-seated sepsis. A Line of incision. Amount of bone to be resected is represented by a b c. B Procedure completed.

be located by roentgenograms following the injection of radiopaque substances into the sinuses To utilize Girdlestone's procedure only as a last resort or life-saving measure however, misplaces his emphasis on early, rather than late operation.

As a preparatory measure, Girdlestone recommends that the patient be immobilized on a traction frame or in a body cast, if the latter, the operation should be performed through a large window in the cast The preoperative treatment, both constitutional and local, should otherwise be thorough in every respect and an ample supply of blood for transfusions during and after operation should be available.

Resection of Hip (Girdlestone)—The skin incision is made in an anteroposterior plane, beginning one inch posterior and distal to the anterior superior spine, and extending posteriorly to a point which places the center of the incision approximately one inch proximal to the greater trochanter With the skin edges retracted, the fascia overlying the gluteus medius and a portion of the gluteus maximus is exposed. Two incisions are then made in line with the edges of the retracted skin incision the proximal incision divides the glutei down to the ilium just above the acetabulum The sweep of the scalpel along the distal edge of the skin incision exposes the lateral aspect of the greater trochanter By means of a chisel directed proximally and obliquely toward the superior aspect of the base of the neck of the femur, the trochanter is divided and removed with the incised gluteal mass Upon completion of this procedure the entire anterior and superior aspects of the capsule of the joint are in the open. The femoral nerve anteriorly and the sciatic nerve posteriorly are not approached The capsule and synovium are next excised, thereby exposing the head and neck of the femur the rim of the acetabulum and the remnant of the trochanteric region. If the head of the femur is not necrotic, the procedure is terminated here If the joint is ankylosed the head and neck of the femur are undisturbed

In other cases, the neck of the femur is divided at its base with a 1½ inch chisel and the head and neck are removed thus providing complete saucerization and insuring effective drainage Removal of the head of the femur is facilitated by excision of a portion of the acetabular rim. All necrotic and infected bone is curetted from the acetabulum In the presence of an intrapelvic abscess, sufficient bone is removed from the acetabular wall and the ilium to permit free drainage The excision should be as complete as possible leaving only raw surfaces of vascular cancellous bone

Should an abscess be found extending along the lesser trochanter into the adductor region an additional incision is made on the inner proximal aspect of the thigh and a sufficient amount of the pectineus, adductor longus and adductor brevis muscles is resected to provide adequate and continuous drainage

To maintain drainage the side of the wound is lined with petrolatum gauze. The remainder of the wound is filled with two or three strips of corrugated rubber tissue and gauze These strips are placed from the outside to the depths of the wound in such a way as not to become wrinkled or to block drainage

After Treatment.—The hip is immobilized by a cast or by traction, usually in 160 or 150 degrees flexion Girdlestone notes that it is particularly impor

tant that upward displacement of the femur be prevented, otherwise, the purpose of the procedure, saucerization of the area, will be defeated and drainage from the acetabulum will be blocked.

Such an extensive operation will produce one of two conditions ankylosis, or a rather useless type of pseudarthrosis, wherein weight bearing is almost, if not entirely impossible. The degree of shortening which follows is alone materially disabling For these reasons, such a radical procedure should be undertaken only after serious study and deliberation

PROCEDURES FOR RESIDUAL STAGE

Following treatment of acute infectious arthritis of the hip joint, the ideal result is a normal range of motion with little or no residual arthritic changes. *Prior to the introduction of the antibiotics such an end result would have been* unique, to say the least It is now a distinct possibility, provided treatment is instituted early and is adequate Even with the best of treatment, however a number of patients will have a residual disability Those treated too late or *too little may be expected to present themselves with the complications which* have previously been expected in association with this disease.

Disability following acute infectious arthritis of the hip may present itself in one or more of the following forms

(a) *Pain. If of sufficient degree to preclude weight bearing pain may* be secondary to incongruous articular surfaces and arthritic changes, or it may be induced by an abnormal weight bearing position and instability secondary to a pathologic dislocation

(b) Loss of function from partial or complete ankylosis. Function is proportionate to the degree of limitation and the direction of the range of motion Even a few degrees of painless motion if in a useful position, is preferable to a considerable range of motion in a functionless position

(c) Deformity The common deformity is flexion and adduction. In growing children, the hip joint has a tendency to assume the position of adduction and flexion even though ankylosis took place originally with the joint in the optimum position. Preventive treatment should be carried out during the acute stage, after subsidence of the acute symptoms, deformity alone, without other complications, may be extremely disabling

(d) Instability This may vary in degree with loss of bone substance. With the remnant of the neck and head in the acetabulum, instability may consist only of a mild or moderate hip limp Following complete loss of the head *and neck of the femur and upper displacement of the trochanter and shaft onto* the wing of the ilium instability may be so extreme as to prevent any weight bearing on the affected side

(e) Shortening of the affected extremity Shortening may be the result of loss of bone separation of the upper femoral epiphysis, or a pathologic dislocation. Harmon has called attention to the fact that cessation of growth in the upper femoral epiphysis contributes little to the loss in length of the extremity over a period of years rather the degree of shortening depends largely upon the other factors mentioned above

To cover every contingency which might arise following acute infectious arthritis of the hip joint, and to give in detail the indications and contraindica

tions for all the appropriate procedures would necessitate an extensive chapter in itself For brevity's sake, various operations are listed below, with a brief outline of their applicability to each of these disabilities.

Months, or even years, may elapse after the acute process has subsided before a reconstruction operation should be undertaken There are a number of reasons for delaying reconstruction of the hip First, the danger of relighting an old infection is reduced If osteomyelitis has been associated, an exacerbation of the infection is a distinct possibility Further with the elapse of time, evolutionary changes may take place in the bone which favor success, namely, the density and growth of the bone may become relatively normal abscesses or cavities may be eradicated and necrotic bone may become revascularized. On the other hand to permit a fixed deformity to persist indefinitely over a number of years or a *pathologic dislocation or unstable hip to remain untreated* during the growth period is highly undesirable

Many factors must be taken into consideration before any of the following operative procedures are carried out For example a roentgenogram of the hip made during the early stage of the disease may show an apparently complete septic necrosis of the head of the femur and possibly an impending or partial separation of the upper femoral epiphysis. With the continued use of traction while the patient remains in bed, and subsequent prevention of weight bearing over a period of months, the head may be revascularized and the head and neck may unite in a fairly functional position. Precipitate surgery, before the status of viability of the head is definite, is to be avoided.

The operations commonly employed for reconstruction of the hip are the following arthroplasty correction of deformity stabilization and equalization of leg lengths

Arthroplasty

Arthroplasty is performed for either of two particular types of disability a mobile but painful hip or an ankylosis. In the presence of excessive pain and disability in a mobile hip arthroplasty with the use of a Vitallium cup may provide a *satisfactorily functioning member* Under these circumstances, the indications for arthroplasty closely parallel those for hypertrophic arthritis of the hip Both the indications and contraindications for arthroplasty for ankylosis of the hip following acute infectious arthritis are described in detail in Chapter XVII

Correction of Deformity

As a rule, deformity should be corrected as soon as feasible after the acute *infection has subsided* In the presence of flexion and adduction, transference of the crest of the ilium perhaps with adductor tenotomy may produce a satisfactorily functioning extremity with a material decrease in disability If the hip is solidly ankylosed in a position of flexion and adduction subtrochanteric osteotomy (Ch. XVI) will place the hip in a desirable weight bearing position despite the ankylosis. In young children the most advantageous position is 150 degrees abduction Parents of young children who undergo this procedure should be advised that a second osteotomy may be necessary as the deformity may recur before the child reaches maturity

Stabilization

Four types of stabilizing operations may be utilized for acute infectious arthritis (1) arthrodesis, (2) shelf operation (3) Schanz osteotomy, and (4) the Harmon, or L'Episcopo reconstruction type of osteotomy

Arthrodesis (Ch XV) most often employed in adults, promises a more certain end result than the majority of the other types of reconstruction procedures The disadvantages of elimination of motion are obvious. On the contrary, arthrodesis does provide a stable and painless member and in many cases is the most practicable type of reconstruction for either pain or instability This is particularly true if the patient's occupation involves manual labor or standing for long periods of time.

Shelf operations similar to those for congenital dislocation of the hip (Ch. XXV) may be utilized for loss of the upper end of the neck and the head of the femur These procedures are seldom applicable to adults A bony support being provided for the upper end of the femur the hip lurch is less pronounced and mobility is preserved Pain however may eventually necessitate an arthrodesis.

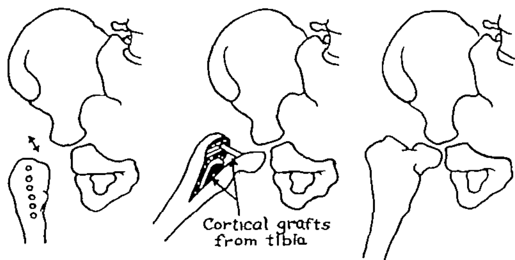


Fig 181—Harmon reconstruction procedure for loss of head and neck of femur in a young child, following acute infectious arthritis. After a period of growth, and weight bearing functional adaptation produces a rather substantial structure. (Harmon, Paul H. J Bone & Joint Surg 24 576, 1942.)

Subtrochanteric osteotomy (Schanz) may be employed if the remnant of the neck in the acetabulum is adequate In these cases a lurching gait may be materially improved Function is also improved by an apparent increase in the length of the extremities, provided by the abducted position of the extremity Such a procedure is ordinarily not indicated unless some portion of the femur articulates with the acetabulum.

In the L Episcopo and the Harmon reconstructions a new neck of the femur is reconstructed which articulates with the acetabulum. Harmon has described a longitudinal type of osteotomy which is particularly applicable to young children following absorption of the head and neck of the femur by pyogenic infection He observed that, in most cases of pyogenic infection despite the absorption of the head and neck, the contour of the acetabulum remains relatively undamaged.

Harmon points out that this longitudinal osteotomy is a procedure designed primarily for very young children Because of the extended period of growth which may be anticipated, function will produce through stress and strain a comparatively substantial neck and trochanter

Technic (Harmon)—Through an anterior iliofemoral incision the hip joint and the upper one fourth of the femur are exposed The periosteum is stripped from the anterior aspect of the upper portion of the femur and four to six holes are drilled through the femur in an anteroposterior direction During this procedure, the extremity should be in a neutral position as to rotation The acetabulum is denuded of all fibrous tissue, with care to avoid injury to the cartilaginous surface. Utilizing the holes drilled in the shaft as a guide, the femur is osteotomized longitudinally, it is then fractured in greenstick fashion and the medial fragment is pried medially Bone grafts from the tibia of the opposite extremity are placed in the osteotomy site to serve as struts or props to support the medial angulation of the medial fragment The medial fragment is then brought into the acetabulum. The muscles attached to the trochanter are not disturbed during any of this procedure.

After Treatment.—A plaster cast is applied from the nipple line to the toes on the affected side and to the knee on the opposite side, maintaining the affected hip in neutral rotation and slight abduction. Immobilization is continued for three months Thereafter, the patient is allowed to walk with crutches and gradually, over a period of months, to bear weight on the extremity

Equalization of Leg Lengths

A procedure for equalization of a discrepancy in length is carried out only after reconstruction operations are completed on the affected side Equalization may be accomplished by shortening the long extremity by osteotomy (Chapter XXII) or by arresting epiphyseal growth (Chapter XXII)

SACROILIAC JOINT

Acute infectious arthritis seldom involves the sacroiliac joint. Infections of this region are practically limited to osteomyelitis of the ilium or sacrum adjacent to the joint. The treatment may therefore be found under that subject.

SPINE

As a rule, infectious lesions of the articulations of the vertebrae are not sufficiently acute to give rise to large pyogenic abscesses requiring drainage unless associated with osteomyelitis. When abscesses do develop, however, drainage may be instituted as described in the section on Complications of Tuberculosis of Joints.

STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

Acute pyogenic infection of these joints usually is associated with an infectious process in other joints. Because of their superficial location, incision and drainage present no more difficulties than similar treatment of superficial soft tissue abscesses. As in the hip, healing may take place without drainage extensive destructive changes in the bone are rarely observed and ankylosis is

uncommon. Residual limitation of motion produces relatively little disability Pathologic dislocation of either joint may occur occasionally but usually is not sufficiently disabling to warrant surgical intervention

SHOULDER

Distention of the capsule of the shoulder joint with stretching of the peri articular surfaces may cause a subluxation, which is too often regarded as of traumatic origin. Such displacement is of no significance as symptoms subside and muscle tone returns, the head gradually approximates the glenoid cavity

Aspiration

The shoulder lends itself readily to aspiration anteriorly posteriorly or laterally As the fluctuant area is most often palpated over the anterior sur face, the needle usually is inserted at this point. Treatment by irrigation, ac cording to the Cotton technic as described for the knee, may be advantageous.

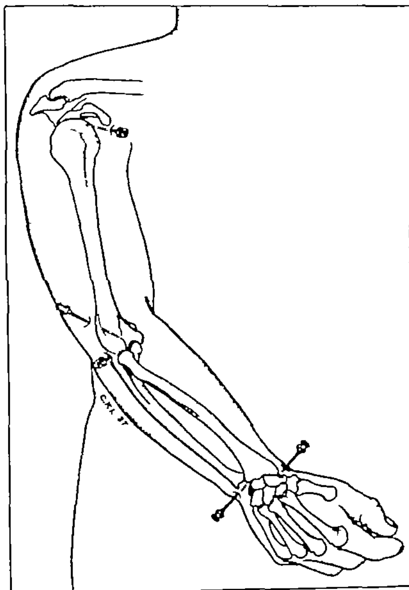


Fig. 182.—Aspiration of wrist elbow and shoulder joints.

Drainage

Drainage may be accomplished through either the anterior or posterior approach though preferably the former

Anterior Incision—Technic.—A straight incision two or three inches in length is made over the center of the anterior aspect of the head of the humerus, beginning at the anterior border of the acromion The superficial and deep fasciae are incised the fibers of the deltoid muscle separated, and the capsule is opened under direct vision A tube is inserted down to the joint and fixed to the skin incision by silkworm gut sutures.

Posterior Incision—Technic.—This incision begins at the base of the spine of the scapula and extends for a distance of three inches downward and outward in line with the fibers of the deltoid muscle The muscle is divided longitudinally revealing the short external rotators of the shoulder joint. Dissection is carried between the infraspinatus and teres minor muscles just medial to the greater tubercle of the humerus. The capsule is exposed incised, and treated in the same manner as following the anterior incision

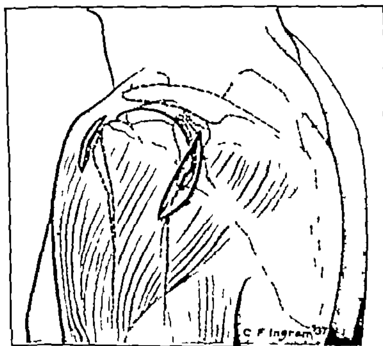


Fig. 181.—Anterior and posterior drainage of shoulder

After Treatment.—The shoulder is supported by a splint which holds the joint in 135 degrees' abduction When acute symptoms have subsided, physical therapy should be instituted.

ELBOW

Aspiration

To aspirate the elbow the joint should be held in acute flexion and the needle inserted on the posterior aspect immediately lateral to the olecranon In attenuated infections the joint may be effectively treated by irrigation

Drainage

Drainage is accomplished preferably by either the medial or lateral approaches, or by both

Medial Incision—Technic.—An incision is made directly over the internal condyle, from two inches above to one inch below the joint. By this approach the ulnar nerve, which lies behind the internal condyle is avoided. The superficial and deep fasciae are incised and the space between the triceps muscle posteriorly and brachialis anteriorly is developed The periosteum is elevated downward and laterally to the joint. The capsule is opened and spread wide with forceps, and a tube of petrolatum gauze is inserted for drainage

Lateral Incision—Technic.—This incision extends from two inches above to one inch below the external condyle. The triceps and extensor carpi radialis longus muscles are separated and raised subperiosteally exposing the capsule. Injury to the radial nerve as it curves anteriorly is avoided by dissection close to the bone. The capsule is incised freely and a petrolatum wick is inserted to maintain drainage

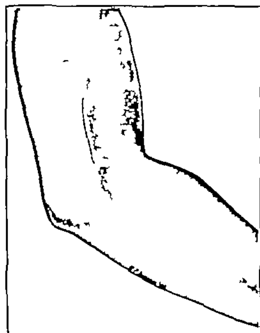


Fig. 184.

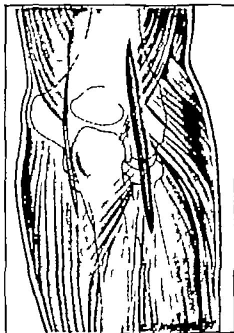


Fig. 185.

Fig. 184.—Line of skin incision for lateral drainage of elbow
Fig 185.—Incision on each side of triceps aponeurosis for posterior drainage of elbow

The posterior compartment also may be drained through this incision by dissection posteriorly along the humerus and elevation of the attachment of the triceps from the lateral surface of the humerus.

Posterior Incision—Technic.—Parallel longitudinal incisions are begun on each side of the olecranon process and continued proximally for three inches. The incisions are extended through the medial and lateral borders of the triceps aponeurosis into the posterior compartment of the elbow joint. *Care should be exercised to avoid injury to* the ulnar nerve as it passes across the posterior aspect of the medial condyle of the humerus.

After Treatment.—A simple splint is applied, holding the joint at an angle of 90 degrees, with the forearm in supination If the process is acute, hot wet dressings may give material relief and reduce or prevent cellulitis. As the articular surfaces are closely approximated, permanently restricted motion from fibrous ankylosis, extra-articular contracture, or bony ankylosis may result.

WRIST

Aspiration

For aspiration of the wrist, the needle is inserted into the joint from the dorsal aspect just medial to the anatomic snuffbox (See Fig 182)

Drainage

Drainage is accomplished by a medial lateral or posterior incision Caution should be exercised to avoid opening the tendon sheaths, as tenosynovitis may be a serious complication

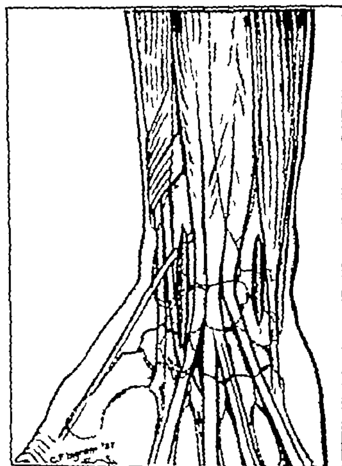


Fig. 188.—Incisions for dorsal drainage of wrist joint.

Lateral Incision—Technic.—A lateral incision two inches in length *is made* between the tendons of the abductor pollicis longus and extensor pollicis brevis, and the extensor pollicis longus muscles, into the anatomic snuffbox. *The radial artery* which passes to the dorsum of the wrist, is retracted. The radial collateral ligament and synovium are incised longitudinally A *petrolatum* wick is inserted for drainage.

Medial Incision—Technic.—A two-inch incision is made over the head of the ulna on the medial aspect of the wrist, between the flexor and extensor carpi ulnaris tendons. The ulnar collateral ligament and synovium are exposed and incised just distal to the styloid process. The attachment of the triangular intra articular cartilage to the styloid process of the ulna must not be disturbed.

Dorsal Incision—Technic.—This incision, two inches long passes through the dorsal carpal ligament, thence between the tendons of the extensor pollicis longus and the extensor indicis proprius, or on the inner side, between the extensor carpi ulnaris and extensor digiti quinti proprius.

After Treatment.—The wrist is held in dorsiflexion or extension by a cock up splint to permit free motion of the fingers and metacarpophalangeal joints. Hot wet dressings are applied continuously for several days. Active motion is instituted as soon as the process subsides and is practiced consistently until function becomes relatively normal.

WOUNDS OF JOINTS

Wars provide the impetus for a tremendous advancement in the treatment of contaminated or septic wounds. World War II was no exception, and the treatment of wounds of joints shared in this progress in no small measure. The present discussion will deal largely with the newer concepts of treatment with particular reference to wounds of the knee In most other joints, such as the foot and ankle, elbow or wrist the problem is chiefly that of a compound fracture.

Following World War I, Willems described a treatment of gunshot wounds of joints which, in cases observed early, consisted of debridement of the wound, removal of foreign bodies and devitalized tissue and, finally lavage of the joint and closure of the wound in late cases, the wound was packed open Upon these points, there was little disagreement among the majority of orthopedic surgeons. The after treatment which Willems recommended however was less widely accepted He advocated immediate mobilization of the joint, with active motion every one or two hours during both day and night. Even in the presence of extensively draining wounds and sinuses, motion was encouraged in an endeavor to force the infectious material out of the joint. We mention Willems treatment here only to condemn it and record it as a thing of the past.

Joints, particularly the knee joint with its extensive synovial lining possess considerably more immunity to infection than do bones, tendons, or periarticular structures Wounds of the joint have been observed wherein the synovial membrane and capsule have been closed tightly without infection, only to have an extra-articular abscess form in the subcutaneous structures Formerly primary closure of wounds of joints was followed by a disappointing number of infections. Chemotherapy and antibiotic therapy have now made it possible to close the majority of wounds of joints provided early and adequate surgery is carried out

Burns, Young and Muller observed a remarkable lack of gram positive infections in an extensive series of war wounds of the knee joint which were treated by penicillin rather the majority of infections were caused by gram

negative organisms of the coli group and by *B proteus* Even suppurative infections were considerably less severe than one might expect, usually being of a subacute nature

Hampton obtained very satisfactory results even in potential or established infections of war wounds of knee joints by debridement, introduction of antibiotics and closure of the synovium Adapting Hampton's war experiences to civilian life, we have drawn heavily from this source in the preparation of the subsequent section

The choice of treatment for wounds of joints depends upon two factors the time element and the type of the wound The time element assumes far less importance in wounds of joints in determining the advisability of surgery and closure of wounds, than in injuries elsewhere, if one anticipates preserving motion the synovium should be closed Exposed joints are certain to develop mixed infections and the exposed cartilage degenerates rapidly With the exceptions to be mentioned later the duration of the wound plays a relatively minor role.

Wounds of joints may be classified as Type I, II, and III In a Type I wound injury of the soft tissues is of minor degree and for practical purposes, injury to bone or joint surfaces is nil A puncture wound from falling on a nail, cotton stalk, or other jagged object, might cause a Type I injury Another common example is a through-and through bullet wound.

In Type II wounds, the soft tissue damage may be relatively extensive, though maceration and necrosis is only slight and little foreign material is present in the joint or soft structures. Common examples of this type of wound are the average compound fracture of the patella, and a bullet wound involving the bone to a moderate or extensive degree, the bullet being lodged in or near the joint.

Type III wounds are those wherein the soft tissue damage is severe foreign material is present in the wound, there is considerable necrosis of tissue and the synovial membrane and capsule are widely lacerated. In addition the bone injury is frequently extensive A close range shotgun wound is an example of his type of injury For a wound to fall in this category damage must be sufficiently severe to conclude that preservation of a functional or movable joint is improbable

Treatment of Type I Wounds.—In most Type I injuries, treatment may be relatively conservative Small puncture wounds, such as those made from a nail need not be explored if one is fairly certain that foreign material does not remain in the soft tissue or in the joint This is also true of through and through bullet wounds. If loose particles of bone or foreign material are free in the joint, treatment should be carried out as for a Type II wound.

A chemotherapeutic or antibiotic agent should be administered both locally and parenterally and the joint should be immobilized A distended joint should be aspirated to permit one to determine the type of fluid and whether any pathogenic organisms are present. Aspiration should be repeated as often as necessary to evacuate the fluid from the joint. If the fluid is kept at a minimum pain is materially relieved and flexion contracture is less likely To allow a hemarthrosis to persist indefinitely is to invite a residual and stubborn synovitis which may prolong recovery

After Treatment.—(See below.)

Treatment of Type II Wounds.—The external wound is treated by the usual methods of preparation and debridement (p 374). While the damaged tissues are being excised, the gloved hand should not come in contact with the joint and, prior to entering the joint, the instruments should be changed. With closure in mind the contused edges of the synovial membrane and capsule are trimmed away as conservatively as possible. The joint is thoroughly explored and débrided of blood clots, loose particles of cartilage, comminuted fragments of bone and foreign bodies. Metallic bodies buried in the bone, if readily accessible, are removed with the adjacent devitalized bony tissue. If exposure is difficult or must be extensive foreign bodies may be left in situ and removed later, if necessary. Metallic bodies lodged in the condyles of the femur or tibia some distance from the joint should not be disturbed; their removal would necessitate an extensive exposure of cancellous bone, materially increase the operative trauma and perhaps tip the scales in favor of an infected joint.

The joint should be carefully examined with a view to ultimate restoration of function. All bone edges are smoothed and the joint is then irrigated with copious quantities of normal saline solution to remove minute fragments of debris. Prior to closure the vessels are ligated. The synovial membrane should be closed with a plain catgut suture preferably so inserted that none of the suture material enters the joint. Antibiotics are introduced with a needle through the closed synovium into the joint. If introduced prior to closure, most of the fluid will escape. If loss of tissue precludes closure of the synovial membrane or capsule, a flap of fascia or skin should be shifted to eradicate the defect. In many cases, the skin may also be closed. If the superficial portion of the wound is left open secondary closure may be possible on the fourth or fifth day.

After Treatment.—The joint is immobilized and maintained in the optimum position by means of a Buck's extension. In addition systemic treatment is carried out as for a septic patient (p 11).

The presence or absence of infection is determined by the constitutional reaction of the patient, with particular reference to the temperature and pulse, by the local manifestations of inflammation in the joint, and by cultures from the fluid aspirated from the joint. In order to maintain the fluid in the knee at a *minimum level, aspiration every twenty-four to forty-eight hours* may be necessary. On these occasions chemotherapeutic or antibiotic agents may be introduced into the joint.

Even though the reaction may be of slight degree, restoration of motion in the joint should not begin prior to two weeks, and usually not before three weeks. Convalescence, however may be materially facilitated by active contracture to maintain muscle tone. This may be accomplished without moving the joint. The patient is first taught to move the patella voluntarily by contracture of the quadriceps muscle on the normal side, and then to apply this to the affected extremity. Passive and active motion may be instituted after all acute symptoms have subsided.

Function cannot be coerced, but must be induced slowly; otherwise, a reaction will take place which may cause an exacerbation of the infection or a residual synovitis, and defeat the purpose of treatment. Exercise is practiced

three hours, beginning cautiously For this purpose, the extremity may aced in a Thomas splint with a hinge at the knee (Fig 60), and an over apparatus utilized, as in the postoperative treatment of arthroplasty of knee. Special exercises should be carried out to restore the normal power e quadriceps muscles as rapidly as possible. When walking is permitted, a ol dial or drop ring catch knee brace (Fig 20) should be applied to permit dual increase of the range of motion. A tendency toward flexion deformity sts even following the establishment of a functional range of motion This be overcome through the use of a long night splint for several weeks after symptoms subside The night splint and brace are not discarded until a factory range of active motion, particularly extension, is restored

Treatment of Type III Wounds.—In the majority of Type III wounds, assumed that infection is a distinct possibility, or even a probability and restoration of a movable joint is a remote possibility To the point of re, the treatment is identical to that described for a Type II wound If wound is fresh and the joint surfaces are irreparably damaged, primary n may be considered.

After completion of surgery, three alternatives are then available First, synovium may be closed, without closure of the subcutaneous structures and Second the original wound may be drained by means of a loosely packed olatum gauze. On the fourth or fifth day the wound is dressed aseptically pon clinical observation only it appears clean it may be closed secondarily d, the joint may be drained through parallel anterior incisions and postero- ial and posterolateral incisions. All wounds are kept open with petrolatum e down to but not within, the joint.

The choice between these procedures depends less upon the time element the type of the wound also upon the thoroughness with which surgery be carried out In close range shotgun wounds, for example adequate dé- ement may be anatomically impracticable or impossible thus, infection of e degree is inevitable and incision and drainage are in order The possi ies of gas gangrene must be considered. If one is in doubt as to the proper tment temporary drainage followed on the fourth or fifth day by a sec ary closure is a safe alternative Severe wounds should be closed completely if less than six hours old and thorough debridement is possible.

In the presence of actual or potential infection of a Type III wound every mpt should be made to remove metallic fragments imbedded in the bone r the joint. Otherwise these bodies will serve as a constant source of irrita maintaining drainage and leading to the formation of sinuses.

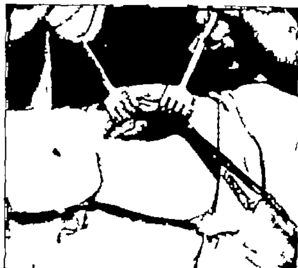
After Treatment.—(See above)

Subacute or Chronic Infection

Hampton employed essentially the technic outlined above for Type II in ies, for war wounds of knee joints with potential or established sepsis, namely e exposure, thorough removal of devitalized tissue and blood clot, closure the synovium or capsule instillation of antibiotics and immobilization of the it. This management was applied regardless of the time interval between iry and the initial treatment. Closure of the synovium and the success of procedure was, of course predicated on adequate excisional surgery and on

A

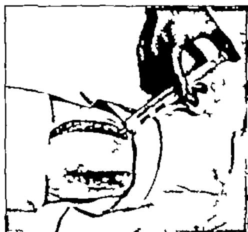




B

Fig 187.—*A* Infected joint with purulent material draining from open granulating wound fifteen days after injury. *B* Joint visualized through anteromedial incision. Quadriceps pouch filled with debris and fibrinous exudate. Comminuted fracture of patella with degenerated cartilage poorly visualized. Small piece of cloth, removed from joint, is shown on gauze at left of incision. (From Hampton, O P Jr J Bone & Joint Surg 28 650 1946.)

A





B

Fig 188.—Same as Fig 187 *A* Patella has been removed joint cleansed and synovial membrane sutured and joint is being filled with penicillin. *B* Fragments of patella, a bit of cloth, and some of the fibrinous exudate. (From Hampton, O P Jr J Bone & Joint Surg, 28 650 1946.)

A





B

Fig. 189.—Same as Fig 187 *A* Parallel incisions in skin closed. *B* Wounds healed, satisfactory range of motion three and one-half weeks after operation. (From Hampton, O. P., Jr : J Bone & Joint Surg 28 650 1946.)







Fig. 100.—*A* Suppurative arthritis of the knee joint of three weeks' duration, superimposed on a comminuted fracture of condyles and supracondylar region of femur. Patient also had a laceration of patellar tendon. Knee ready for surgery. *B*, Hopelessly destroyed joint surfaces. *C* Resected portions of articular surfaces of femoral and tibial condyles. (From Hampton, O. P., Jr.: J. Bone & Joint Surg. [illegible]: 650, 1916.)

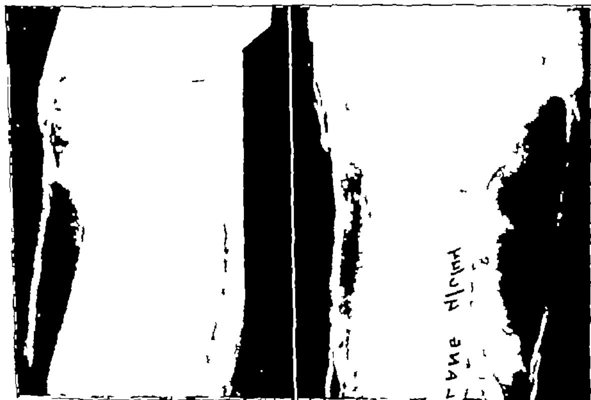


Fig. 101.—Same as Fig. 100. Roentgenograms of resected knee. Patient obtained a firm fusion. The object of above technic, however, was control of sepsis with wound healing, not primarily arthrodesis. Optimum result for this [illegible]

a sufficiently well preserved joint to anticipate motion Wounds were left open only when all hope of a functional joint were abandoned

In order to eradicate or prevent continued drainage and sepsis, or in joints that were hopelessly destroyed, Hampton resorted to resection and fusion, in most instances, thereby promoting early healing The extent of the bone loss or destruction determined the extent of excision and the resultant shortening ordinarily about one and one-half inches.

In civilian practice, resection, we believe is indicated for chronic sepsis of the knee only in lieu of amputation Certainly with a partially ankylosed joint in a poor position destruction of joint surfaces, and persistent drainage from a low grade infection, the procedure would be worth while Unless shortening is extreme (more than 2 or 2½ inches) the function would be superior to a mid thigh amputation and an artificial limb

References

Badgley C E., et al.: Study of the End Results in 113 Cases of Septic Hips, J Bone & Joint Surg 18 1047 1936.

Brackett, E. G and Osgood, R. B. The Popliteal Incision for the Removal of Joint Mice in the Posterior Capsule of the Knee Joint a Report of Cases, Boston M. & S. J 165 975 1911.

Burns, B. H., Young R. H., and Muller G M. Wounds of the Knee-Joint, Lancet 1 551 1945

Buxton, St. J D Gunshot Wounds of the Knee-Joint (Hunterian Lecture) Lancet 1 681, 1944.

Carney P W., Fitts, W T Jr., and Kirby C. K. Gunshot Wounds of the Major Joints, J Bone & Joint Surg 28 607 1946.

Cotton F J Disinfection of Septic Joints, J Bone & Joint Surg 8: 895 1926.

David, S. D Experimental Incision on the Cadaver for Drainage of the Ankle Joint, J Bone & Joint Surg 5 480 1923

Freiberg J A., and Perlman Robert Pelvic Abscesses Associated with Acute Purulent Infection of the Hip Joint, J Bone & Joint Surg 18 417 1936.

Girdlestone G R. Acute Pyogenic Arthritis of the Hip. Operation Giving Free Access and Effective Drainage Lancet 1 419 1943

Hamilton J F Diagnosis and Management of Gonococcal Arthritis, With Emphasis on the Use of Ammonium O-Iodoxybenzoate South. M. J 29 791, 1936.

Hampton, O P Jr Observations on the Management of Suppurative Arthritis of the Knee Joint Am. J Surg 74 631 194.

Hampton O P Jr The Management of Penetrating Wounds and Suppurating Arthritis of the Knee Joint in the Mediterranean Theater of Operations, J Bone & Joint Surg 28 659 1946.

Harmon, P H. Surgical Treatment of the Residual Deformity from Suppurative Arthritis of the Hip Occurring in Young Children, J Bone & Joint Surg. 24 576, 1942.

Harmon, P H., and Adams, C O: Pyogenic Coxitis End Results and Considerations of Diagnosis and Treatment Surg., Gynec. & Obst. 78 371, 1944.

Henderson, Melvin S. Posterolateral Incision for the Removal of Loose Bodies from the Posterior Compartment of the Knee-Joint, Surg. Gynec. Obst. 33 698, 1921.

Jones, Hugh Toland The Treatment of Acute Purulent Arthritis by Joint Washing and Closure, J Bone & Joint Surg. 17 559 1935.

Jones, H. T The Treatment of Acute Purulent Arthritis by Joint Washing and Closure J Bone & Joint Surg. 17 559 1935.

Key J A. Joint Infection and Arthritis (Except Tuberculosis) Bancroft & Murray Surgical Treatment, Philadelphia, 1945 J B. Lippincott Co

Key J A. Penicillin and Sulfonamides in the Treatment of Osteomyelitis and Pyogenic Arthritis, Bull. New York Acad Med. 21 87 1945

Ober Frank R Posterior Arthrotomy of the Hip Joint. Report of Five Cases, J A. M. A. 83 1500 1924

Putti, V La Capsulotomia Poplitea Nella Cura Della Retrazzioni Fles Sorie del Ginocchio Chir d. org di movimento 5 1, 1921.

Willems, C. Immediate Active Mobilization in the Treatment of Gunshot Wounds of the Joints, M. Rec. 95 903 1919

— Treatment of Purulent Arthritis by Wide Arthrotomy Followed by Immediate Active Mobilization, Surg Gynec Obst 28 546, 1919

CHAPTER VI

TRAUMATIC AFFECTIONS OF JOINTS

Lesions of joints in which trauma plays a part constitute a large group of joint affections. These lesions may be classified as follows

1 Acute traumatic arthritis or synovitis with progressive pathologic changes induced solely by trauma as sprained ankle or ruptured internal semilunar cartilage

2. Arthritis associated with other clinical entities in which trauma may have been the instigating agent although symptoms referable to the primary injury have subsided as in Kümmell's disease or Kienböck's disease

3 Arthritis in which trauma is a definite factor in exaggerating or producing symptoms of other pathologic entities already present as low grade infectious arthritis, gout hypertrophic arthritis or osteoarthritis and syphilis.

Only those lesions of the first and second groups which require surgery will be discussed herein The third group of affections is described in Chapter XIII

INTERNAL DERANGEMENTS OF JOINTS

'Internal derangement is now loosely applied categorically to a variety of intra articular and extra-articular disturbances, usually of traumatic origin, which interfere with the mechanics or function of a joint The term is also utilized as a diagnosis to indicate a mechanical impediment whose exact origin is obscure. Although symptoms similar to those produced by derangements of traumatic origin may arise from intra articular tumors or other lesions, the latter are not regarded as strictly internal derangements.

Internal derangements are by far most common in the knee, although they are also observed in the hip elbow temporomandibular and other joints. Because of their preponderance those of the knee will receive detailed attention

In order that the rationale of treatment may be better understood, in the subsequent section we shall discuss in detail the anatomy and function of the knee. Heretofore, a great deal of confusion has existed even as to the anatomy of the joint. This difference has been reflected in the variety of opinions regarding the proper therapy The standard text descriptions of internal derangements which antedate World War II are likely to be incomplete inadequate and even erroneous.

Certain fundamental postulates of the anatomy and function of the structures about the knee were set forth in 1940 by Brantigan and Voshell. Abbott and his associates in 1944 contributed to this subject. These basic concepts, correlated with the vast amount of the information gleaned from surgery of the knees during World War II provide a background for some changes in our ideas of proper therapy A particularly large series of cases are reported in 'Orthopaedic Surgery in the Army Air Forces During World War II,' by Shands, Luck, Smith, and Lacey Smillie has written an excellent treatise on 'Injuries to the Knee Joint, drawn from his vast military experience The reader may

well refer to this last work for up-to-date details. We have drawn heavily from the above sources in the preparation of the subsequent section interspersing our own war experiences and a fairly substantial series of cases from civilian life. For pedagogic reasons we will try to avoid the extremes of controversy and make our statements as specific and dogmatic as possible.

Anatomy and Function of Structures About the Knee Joint

To prevent repetition in subsequent sections of this chapter the basic concepts of the anatomy of the knee joint promulgated by Brantigan and Voshell, and by Abbott and associates, will be presented Their observations would seem to settle most of the major points of difference regarding this subject.

Motion of a Normal Joint.—The architecture of the bones and the arrangement of the ligaments provide a rotary locking of the knee on complete extension. At this point, all of the ligaments are taut, the cartilages being snugly compressed between the condyles of the femur and tibia neither rotation, anteroposterior gliding nor lateral motion can be elicited. With the first few degrees of flexion the tibia rotates 1 to 3 degrees on the femur and the fibular collateral ligament relaxes, remaining relaxed as the joint is flexed. The other ligaments remain taut, though not tense, throughout flexion. With the joint flexed, rotation varies from 6 to 24 degrees. The degree of lateral motion is greatest between 150 and 130 degrees. At 90 degrees, 4 to 9 degrees of lateral motion is present. In normal joints, there is a certain amount of abduction and adduction rocking of the tibia on the femur some anteroposterior movement, and a very minimal degree of mediolateral motion. Only when the integrity of the ligaments is violated do these nonfunctional movements assume importance increase in degree and assume clinical and pathologic stature.

The bony architecture as well as the arrangement of the ligamentous structures, provides for rotation of the femur on the tibia. In the beginning of flexion, the femoral condyles roll backward on the tibial condyles, together with the semilunar cartilages. The amount of displacement is considerably more on the lateral side than on the medial side the relaxation of the lateral ligament permits this greater excursion. This discrepancy in displacement indicates the rotation of the femur on the tibia, thus, the medial femoral condyle must be considered the axis of rotation of the knee joint.

Hyperextension is prevented by both collateral ligaments, both cruciate ligaments, the posterior aspect of the articular capsule the oblique popliteal ligament, the anterior aspect of the semilunar cartilages, and particularly the architecture of the condyles of the femur

Hyperflexion is prevented by the cruciate ligaments the posterior portions of the semilunar cartilages, the femoral attachment of the posterior aspect of the capsule, the femoral attachments of the gastrocnemius muscle, and the architecture of the femur The cruciate ligaments play a particularly important role in both hyperextension and hyperflexion. The action of all of the muscles which pass across the knee joint likewise assumes special significance

Stability of the Knee Joint

To assign a superlative role to any of the structures which stabilize the knee joint would be to disregard the emphasis which Brantigan and Voshell place

upon the inter relation and importance of all structures A normal functioning knee joint calls for complete function of the muscles and tendons, the articular capsule, the cruciate ligaments the lateral ligaments, and normal contour and relationships of the femur and tibia

Muscles and Tendons—The muscles and tendons which pass across the knee joint provide a stabilizing agent susceptible to some active control In this regard the quadriceps muscle is paramount, though the three more frail members of this group of four (medial and lateral hamstring muscles, and gastrocnemius) should not be overlooked

Smillie particularly stresses the importance of the quadriceps muscle in its relation to disability and rehabilitation The extremely rapid loss of tone strength, and voluntary control of the quadriceps group, commonly observed, is out of proportion to muscle atrophy observed in other portions of the body and is unexplainable Atrophy of this structure leads to a vicious cycle of pathologic changes Following injury and subsequent effusion a reflex activity inhibits the quadriceps and produces quadriceps atrophy With weight bearing the active protection of the muscles is lost thereby subjecting the passive stabilizing elements of the joint to trauma and stretching This irritation increases the effusion the effusion demands further immobilization and inactivity which in turn produces further atrophy of the muscles, and another round through the vicious cycle A reversal of this process can be anticipated only when the muscular action tone, and coordination are returned to normal by nonweight bearing weight resisting exercises This is a logical explanation of the emphasis placed on quadriceps exercises in the rehabilitation following injuries to the knee.

In estimating the regression of a quadriceps muscle, or its progress and recovery the key portion of the quadriceps muscle is the vastus medialis Consequently, measurements of the circumference of the middle third of the thigh provide a less accurate check than an inspection of the thigh muscles with the knee joint actively extended. The vastus medialis plays a particularly important role in the restoration of the last few degrees of extension of the joint, i e that portion of the active motion which returns last and requires such sedulous efforts on the part of the patient to regain

Contour of the Bones—For the other stabilizing elements of the knee joint, particularly the passive elements to function properly the contour of the articular surfaces must be normal and the variations from normal alignment of the extremity as a whole must be minimal. The clinical entities of the articular surfaces responsible for instability such as malunited fractures of the tibial plateau or femoral condyles and anterior tilting of the tibial plateau secondary to growth disturbances, are discussed elsewhere.

Ligaments and Capsule.—The articular capsule and the ligaments of the knee joint play an important, but passive role in controlling the stability of the joint. The results of experiments by Brantigan and Voshell may be summarized as follows

> Lateral and rotary motion of the knee joint in extension is controlled by the capsule collateral ligaments, and cruciate ligaments in flexion, by the same structures minus the fibular collateral ligament.

Forward gliding of the tibia on the femur is controlled by the anterior cruciate ligament

Backward gliding of the tibia on the femur is controlled by the posterior cruciate ligament

The role of these structures in controlling hyperextension and hyperflexion has been previously noted

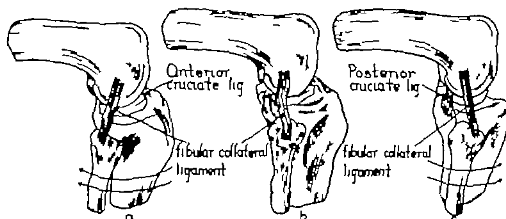


Fig 192.—Bony architecture and arrangement of ligaments permit rotation of tibia on femur *A*, *C* External lateral ligament is taut on both external and internal rotation of tibia on femur *B* With neutral rotation in flexed position, external lateral ligament is relaxed but becomes taut on complete extension. (From Brantigan O C. and Voshell, A. F J Bone & Joint Surg 23 44 1941.)

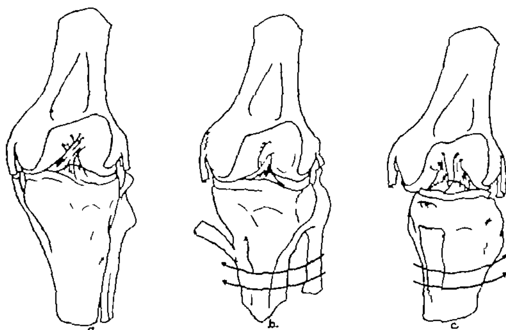


Fig 193.—Stripped joint with both lateral ligaments divided. *A*, There is little or no abnormal lateral motion. *B* Twisting of cruciate ligaments on themselves limits internal rotation of tibia on femur *C* Free lateral rotation of tibia on femur as cruciate ligaments untwist. (From Brantigan, O C., and Voshell, A. F J Bone & Joint Surg. 23 44, 1941.)

It should be pointed out that the cruciate ligaments in their crossed positions prevent abnormal medial rotation of the tibia on the femur by twisting on themselves. Despite the loss in continuity of the collateral ligaments, abnormal medial rotation of the tibia on the femur is prevented by this anatomy however external rotation, wherein the cruciate ligaments are untwisted is

possible to 180 degrees. Since some portion of the medial collateral ligament is taut in all phases of motion, this structure, together with the cruciate ligaments, has an active part in the control of rotation

Inter relation of these two sets of ligaments is again demonstrated by their experiments on lateral motion of the knee joint Contrary to previous opinion, the cruciate ligaments have a highly important function Even though both collateral ligaments are cut, if the cruciate ligaments are intact, the joint is laterally stable If, however, both cruciate ligaments are divided, while the collateral ligaments remain intact, lateral instability is rather marked

In general, the experiments of Brantigan and Voshell show that the tibial collateral and the anterior cruciate ligaments probably add more stability to the knee joint than do the other two, it should be emphasized, however, that the close inter relationship of all the ligaments and the capsule is the chief factor in stability rather than any one ligament

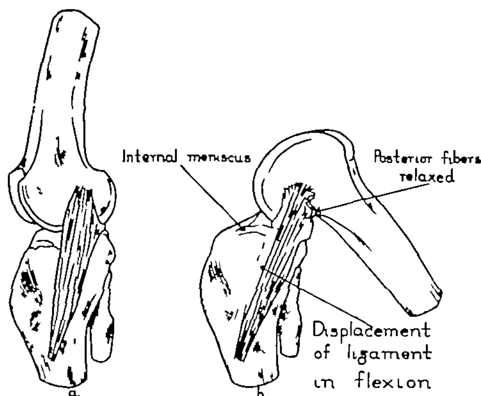


Fig. 191.—Joint stripped to reveal internal lateral ligament. A, Anterior, postero-superior, and postero-inferior portions of ligaments are tense with joint in extension. B On flexion and extension, ligament glides backward and forward on tibia in flexion, posterior oblique portions are relaxed. Note that ligament attaches 4-5 cm. distal to joint. (From Brantigan O. C., and Voshell A. F J Bone & Joint Surg. 23 44, 1941.)

Abbott and associates point out that standard textbook descriptions of the internal lateral ligament are usually inadequate They ordinarily illustrate only the anterior superficial portion of the ligament and do not emphasize the posterosuperior and posteroinferior oblique portions of the ligaments that are attached to the rear of the tibia and play such an important part in controlling rotation. These posterior segments form a more or less hemispherical pouch that grasps the posterior half of the medial femoral condyle in an accurately fitting half bucket this portion being tense on extension, if ruptured can be expected to produce considerable instability to the extended knee In addition they call attention to an anterior deep portion of the internal lateral

ligament which, though definitely blended to the superficial part, is a distinct entity This ligament is shorter than the superficial one and, contrary to the *findings of Brantigan and Voshell, does blend with the margin of* the semilunar cartilage These deep fibers stabilize the medial meniscus and prevent its being trapped between the condyles on motion. Even though the fibular collateral ligament is relaxed in flexion it is an important factor in preventing medial and lateral rotation of the knee joint While this ligament must be relaxed to permit the normal degree of rotation it does become tight beyond the normal range of rotation and, consequently in a degree contributes its portion to the stability of the joint.

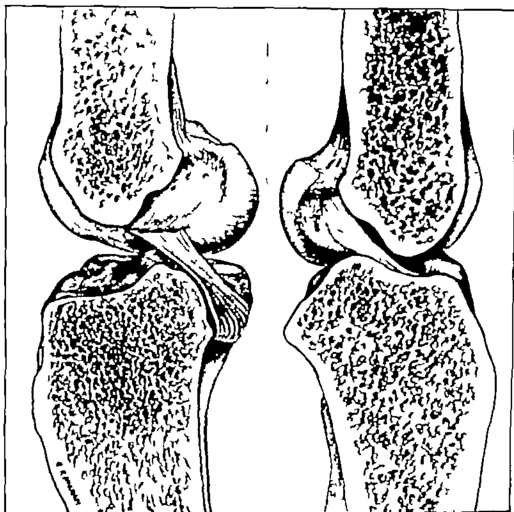


Fig. 195.—Cross section showing anatomy of posterior and anterior cruciate ligaments, respectively

The fact that the cruciate ligaments are set in the joint in both an anteroposterior and a mediolateral, oblique plane, accounts for their importance in stabilizing the joint, not only in an anteroposterior plane, but also as to lateral stability and rotation Abbott differs with Brantigan and Voshell as to the tautness of the anterior cruciate ligament, maintaining that it is slightly relaxed after the first degrees of flexion and that otherwise rotation of the femoral condyle would not be possible. It does, however act as the anchor chain which prevents undue freedom of the lateral condyle The laxity allows a normal

amount of rotation and some degree of adduction On extension the taut anterior cruciate ligament anchors the lateral condyle anteriorly such that hyperextension is only possible by a simultaneous medial rotation of the femur on the tibia This last movement is accomplished by a backward displacement of the medial femoral condyle and therewith the final tightening of all the ligaments The posterior cruciate ligament assumes importance in that it stabilizes the medial femoral condyle throughout flexion limiting the degree of rotation of the femur on the tibia and the amount of abduction of the tibia on the femur Both cruciate ligaments, of course stabilize the anteroposterior elements of the joint

In injured knees there is again some difference among anatomists as to the value of isolated ligaments in stabilizing the joint Abbott and associates agree with Palmer that *section of the tibial collateral ligament does allow some* abduction movement of the tibia in contrast with the statements made by Brantigan and Voshell This occurs only after the joint is flexed a few degrees The division of this ligament also permits some increase in rotation (approximately 15 degrees)

If only the anterior cruciate ligament is ruptured, there is a slight increase in the anterior drawer sign and an increase in extension past 180 degrees, also a slight increase of lateral rotation of the tibia on the femur The anterior drawer sign becomes maximal if the tibial collateral ligament is stretched or ruptured, and with this increase abduction rocking is markedly increased to as much as 30 degrees on marked flexion and to even 10 or 15 degrees with the knee fully extended.

The Mode of Injury of Ligaments of the Knee Joint

The more common mechanisms, according to Abbott are as follows

Hyperextension this stretches the posterior capsule and perhaps even ruptures a few fibers of the posterior cruciate ligament the major injury is a rupture of the anterior cruciate ligament.

Abduction flexion external rotation most commonly this produces in minimal injuries, a tear of the superficial portion of the tibial collateral ligament, particularly its attachment to the femur Further tearing may produce a complete rupture of both superficial and deep fibers, and secondarily a fraying of the anterior cruciate ligament particularly at its superior insertion The mechanism of this latter injury is a matter of rotation. As the lateral femoral condyle rotates medially the anterior cruciate ligament is stretched over the medial edge of the condyle and it must bow medially stretch, or rupture. From this same injury we get medial tears of the semilunar cartilage and, in elderly people, fracture of the tibial condyle

Adduction internal rotation and flexion in this injury the fibular collateral ligament and the anterior cruciate ligament and perhaps even the tendon of the popliteus muscle sustain the injury

Anteroposterior displacement on forceful posterior displacement of the tibia with the joint flexed the *posterior cruciate ligament is torn on anterior* displacement the anterior ligament is involved

Anatomy and Function of the Semilunar Cartilages—Voshell and Brantigan point out reasons why the medial semilunar cartilage is injured so

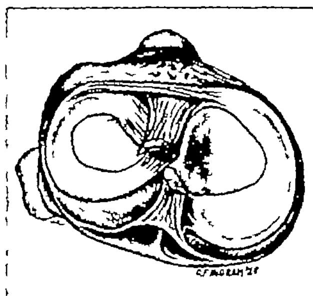


Fig. 196.—Superior view of tibial plateau. The lateral semilunar cartilage is smaller in diameter, thicker about the periphery, wider in body and is more mobile than the medial meniscus.

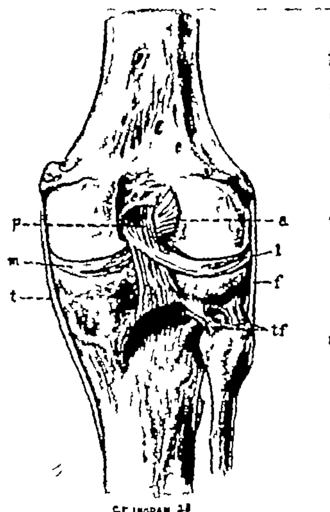


Fig. 197.—Posterior view of stripped knee joint. Internal lateral ligament (t) attaches well distally on the tibia. Ligament of Wrisberg (l) attaches to posterior aspect of external semilunar cartilage, passes behind posterior cruciate ligament, and inserts into medial femoral condyle, thereby stabilizing the lateral cartilage. Ligament of Humphry occupies a somewhat similar position in front of posterior cruciate ligament (p). m, Internal semilunar cartilage. a, Anterior cruciate ligament. f, External lateral ligament. tf, Tibial fibular ligament.

much more often than the lateral The lateral cartilage is smaller in diameter, thicker about the periphery, wider in body, and is more mobile than the medial, it is attached to the anterior cruciate ligament, the posterior cruciate ligament, and, if present, posteriorly to the medial condyle of the femur by the ligaments of Humphry and Wrisberg It is separated from the fibular collateral ligament by the popliteus tendon

The medial semilunar cartilage is much larger in diameter, thinner about the periphery, narrower in body, and has no fibrous tissue attachment to either cruciate ligament It is closely related by areolar tissue to the tibial collateral ligament, though Brantigan and Voshell do not admit the existence of any strong, fibrous tissue attachment to the internal lateral ligament. (This is still a point of controversy) The area enclosed by the medial meniscus is several times larger than the circle enclosed by the lateral cartilage The cartilages are blended intimately with both the synovial membrane and the true capsule, other than where the lateral meniscus is separated from the capsule by the popliteus tendon.

Various functions have been ascribed to the semilunar cartilages, these functions are not too important, however as the knee functions fairly well with out them. Their functions are variously described as follows (1) to serve as shock absorbers between the condyles of the femur and tibia on hyperflexion and hyperextension (2) to prevent impingement of the adjacent soft tissues (capsule and synovium) between the femoral and tibial condyles, i e., filling the space between the periphery of the two bones. (Brantigan and Voshell in roentgenograms of 100 knees noted the average as follows medial side 0 53 mm lateral side 3 48 mm.) (3) to distribute the synovial fluid evenly over the articular surface (Walmsley and Bruce)

Brantigan and Voshell note that the articular contact between the tibia and femur is always present, thus the menisci do not cushion a blow from above or from below We would add, however, that the cartilages do in a measure, serve as cushions to the peripheral edges of the femur and tibia on abduction and adduction movements

ACUTE TRAUMATIC SYNOVITIS

The term acute traumatic synovitis ' is herein used categorically in much the same manner as the term ' internal derangement of joints" is employed Acute traumatic synovitis should not be construed as a diagnosis, but rather as a clinical manifestation of some form of joint trauma caused by one of the lesions classed as internal derangements. The pathologic changes which take place in the knee immediately after trauma depend upon the nature, location, and severity of the injury In view of its function and its vast expanse in the knee joint, the reaction of the synovial membrane assumes particular clinical significance. Following trauma, fluid consisting primarily of large quantities of mucin, forms in the joint from irritation and reaction in the synovial lining cells. This, together with a transudate comprises the fluid elements of the joint effusion The absence of gross blood in the fluid is evidence that the injury was not sustained by a vascular structure, but is limited to avascular areas, such as the articular cartilage or the avascular portion of a semilunar cartilage.

The presence of gross blood i.e., a hemarthrosis, indicates a rent or injury to the vascular components of the joint i e the bone, the cruciate ligaments, the periphery of the cartilage, or the synovial membrane and capsule. Unless *damage to the soft structures or bone is extensive*, blood inside the joint usually does not coagulate but remains relatively fluid, and may be aspirated without difficulty The presence of rather gross clots and excessively large globules of fat is indicative though not pathognomonic of a fracture through the joint surface

With severe distention the normal absorptive and phagocytic action of the synovial lining is impaired. The elements of blood, being foreign to the knee joint, particularly irritate the synovial lining The normal alkaline reaction of the fluid in the joint changes to acid. With the precipitation of blood colloids and fibrin formation, a situation favorable to the formation of fibrous tissue and adhesions is created. If the synovial membrane is too greatly burdened in cleaning up an overwhelming amount of debris, particularly the blood elements, a chronic synovitis may develop with hypertrophy and proliferation of the synovial *folds, and eventual* fibrosis

Rehabilitation of a knee joint depends upon a rapid cessation of this reaction From an understanding of the above pathology the rationale of the therapy described below is apparent

It should here again be emphasized that acute synovitis is merely a manifestation of trauma. Every effort should be exerted to establish the primary diagnosis, ascertain the extent of injury to the structure or structures involved, and institute treatment accordingly

Assuming that roentgenograms are negative and that the history and *clinical examination, in the presence of an acute traumatic reaction*, mask a definite primary diagnosis, the following initial treatment is carried out

1. A Buck s extension is applied with five to seven pounds of traction. This apparatus is utilized to enforce a degree of immobilization, to allay muscle spasm, and to apply gradual force until the knee is straight. To a degree this is also a diagnostic test in the presence of a classical bucket handle tear which does not become unlocked, complete extension will be impossible

2. After proper sterile preparation, the contents of the joint are evacuated by aspiration, (a) to relieve pain from a distended capsule, (b) to prevent undue stretching and tension of the synovium capsule and ligaments, (c) to permit one to determine the nature of the fluid contents of the knee, and (d) as a therapeutic measure to relieve the already overburdened synovial membrane of some of its absorptive and scavenger duties. As stated above, this assumes a special significance in the presence of hemorrhage

3 Hot wet packs are applied. Although their physiologic benefit may be questioned, the packs do provide a *measure of comfort and relief and further* enforce rest to the joint.

After Treatment —More or less constant pressure is maintained on the joint by means of a pressure bandage If fluid redistends the joint to a marked degree, aspiration is repeated. As a rule, within one to four days, unless the joint is locked, definite progress as to regression of the reaction is manifested, pain and muscle spasm subside and the joint is in a relatively functional position. At this time, a more definite diagnosis may be possible. The treatment of specific, traumatic entities is described subsequently in this chapter

Once the acute reaction is under control and if there are no contraindications to rigorous rehabilitation, quadriceps set up exercises are instituted, together with nonweight bearing weight resisting exercises. This is a most important part of the rehabilitation of the joint. Luck divides this convalescent period into three stages (1) the muscle set up or power stage, wherein emphasis is placed upon the maintenance or restoration of muscle power, (2) the mobility stage wherein emphasis is placed upon maintenance or restoration of joint motion, and (3) the coordination stage, during which emphasis is placed upon the restoration of precise, smooth function. Most of the first two stages are carried out while the patient remains in bed, or at best is allowed up on crutches. *The mobility stage should not be started, nor should weight bearing be instituted until the excess synovial fluid has disappeared, and the quadriceps muscle manifests sufficient strength to control the joint adequately.* To do otherwise, invites a recurrence of the synovitis and a vicious cycle of adverse events which lead to a prolonged period of convalescence and rehabilitation (p 249). In the event of a recurrent synovitis, immobilization of the joint and bed rest should be enforced only for a sufficient period to allow subsidence of the fluid in the joint, during this period muscle restoration should be carried out diligently with the knee completely extended. The first two stages of this rehabilitation may require from two to three weeks.

If incomplete tears of the ligaments or indefinite ruptures of the menisci are suspected treatment is carried out as described above with this exception immobilization is enforced by a suspender cast (p 34) as soon as the reaction to trauma subsides. The patient is allowed to bear full weight on the extremity at two weeks. The second and third stages are not begun for six to eight weeks after injury.

LESIONS OF THE SEMILUNAR CARTILAGES

Derangements of the Semilunar Cartilages

Though the semilunar cartilage may be a relatively insignificant structure so far as function is concerned, it assumes paramount importance from a pathologic and clinical standpoint. During World War II, meniscectomy was the most common major operation in orthopedic surgery. In fact, *exclusive of* minor lesions, damage to the semilunar cartilages was more often incurred by military personnel than any other type of noncombatant joint injury. From this vast source of information newer concepts as to the predisposing factors, the mechanism of tears, the classification of tears and their incidence the diagnosis of posterior lesions, the value of conservative treatment, the indications for surgery and postoperative care and complications have evolved.

Factors Predisposing to Injury.—A relatively high percentage of individuals who sustain injuries to the semilunar cartilages will present one or more of the following closely related predisposing factors.

1 Poor knee mechanics. Almost without exception, genu recurvatum is associated with a relatively unstable knee after the first few degrees of flexion. The rotary locking of the knee takes place beyond the normal straight position. Consequently if the recurvatum is as much as 5 or 10 degrees, the knee is unstable to a pronounced degree, even at 180 degrees. This instability manifests itself both in a lateral and a rotary direction. A genu varus or genu valgus

deformity or a tibia vara deformity presents essentially the same amount of instability at 170 to 165 degrees. Disturbed mechanics of other parts of the extremity, as an internal torsion of the tibia or deformities of the feet, do not contribute to the local instability though they do create a certain amount of awkwardness which is not compatible with rigorous athletics, and renders the knee susceptible to injury Instability secondary to genu valgus is caused by stretching and relaxation of the ligaments. Discrepancies in leg length also present a disturbed mechanics which predisposes knee injuries.

2 Degenerative or congenital abnormalities of the semilunar cartilages. Obviously many semilunar cartilages are subjected to trauma which does not necessarily produce a rent or tear, but is of sufficient magnitude to interfere with the nutrition of the avascular portion of the cartilage These lesions may be easily recognized from a section of the gross specimen. In cross section the cartilage contains isolated and spotted areas of yellowish tissue intermingled with white fibrocartilage Obviously such degenerated areas cannot withstand the same degree of trauma as a healthy semilunar cartilage. This is also true of a discoid cartilage

3 Unstable ligamentous support. Ruptures of the anterior cruciate ligament or internal lateral ligament frequently heal with sufficient instability to predispose an intact cartilage to subsequent injury

4. Inadequate musculature does not necessarily indicate muscle atrophy In many young women and in some obese and elderly individuals, joint laxity occurs secondary to loss of muscle tone without superimposed trauma. Unquestionably this renders the knee susceptible to injury and internal derangement.

Normal muscles may be inadequate for a particular situation Rigorous *athletics performed without a proper warm up or without an* adequate development of the muscle for the intended sport, or the performance of athletic endeavors in cold weather may be responsible for a momentary quadriceps insufficiency In an extremely obese individual who has never indulged in athletics the quadriceps may be relatively normal yet still be inadequate for unusual athletic effort. The effect of quadriceps insufficiency secondary to injury has been previously pointed out (p 235)

Mechanism and Classification of Tears.—A rupture or tear of a semilunar cartilage is produced by a torsional or rotational strain while the joint is in partial flexion. Smillie explains this mechanism with particular lucidity since the natural shape elasticity and attachments of the semilunar cartilages tend to inhibit their entrance into the center of the joint, it is unlikely that simple abduction or adduction movements which decrease the pressure on the semilunar cartilages could force the cartilages over into the center of the joint, where they could be trapped or pinched This is particularly true of the lateral cartilage. On the contrary internal or external rotation strains, together with flexion, impose a changed relationship between the femoral condyles and the menisci, eliminating the normal backward and forward excursion *of the cartilages.* On internal rotation, the femur forces the cartilage to the rear and center of the joint. An intact and strong peripheral attachment posteriorly may preclude the subsequent events in the presence of a stretch or tear of the peripheral attachment, however the posterior limb of the cartilage is forced toward the

center of the joint and caught between the femur and the tibia Extension produces a longitudinal rent. If this longitudinal rent extends forward beyond the collateral ligament, the mesial limb is caught between the tibia and femur in the intercondylar notch and cannot return to its former position, thus producing the classical bucket handle tear, with locking

Smillie attributes incomplete transverse rents at the junction of the anterior and middle third of the medial cartilage to this same mechanism this mechanism tends to straighten out the normally concave, mesial portion of the cartilage and the elasticity of the cartilage permits a certain amount of flattening out of the circle, though beyond this point the mesial edge tears at the apex of the angulation This type of tear occurs most often on the lateral side, in that the lateral cartilage represents a smaller circle consequently, even a less pronounced tendency to straighten out its concave edge would produce a transverse rent. Because of its anatomy and mobility, the lateral cartilage is not as susceptible to bucket handle tears from external rotation-adduction forces The combination of cystic degeneration with a transverse tear suggests to Smillie that a direct blow against the periphery of the cartilage may tend to straighten out its concave edge and thus produce both a transverse rent and degeneration

Smillie suggests that the same internal rotation-abduction forces which produce a rent in the medial cartilage might also produce a posterior peripheral rent or if caught, a longitudinal rent of the lateral cartilage Under these circumstances, the external condyle would have to exert an anterior and central force on the anterior limb of the lateral cartilage

With only a little flight of the imagination, these theories would explain some of the more weird and bizarre tears of the anterior third of the medial cartilage and posterior portion of the lateral cartilage

The L-shaped or pedunculated tears are longitudinal rents wherein one limb of the mesial segment is ruptured or absorbed, thereby allowing free excursion.

Hyperextension injuries do not produce true rents or ruptures. The tibial and femoral condyles grip the anterior mesial portion in a nutcracker manner and fray or shred the narrow concave edge of the cartilage A kissing' counterpart of the pathologic change in the semilunar cartilage is *imprinted* in the articular surface of the femoral condyle as an area of degenerated articular cartilage.

The injuries produced by these mechanisms are classified as follows

1 Rupture or tear (a) longitudinal, or classical bucket handle, (b) transverse, (c) oblique

2. Tear of the peripheral attachment (a) posterior horn (b) middle attachment, (c) anterior horn

3 Combined tears of the periphery and of the body of the meniscus

4. L-shaped or pedunculated tears of the semilunar cartilage

5 Frayed, or shredded concave edge

Incidence.—The incidence of traumatic derangement of the internal semilunar cartilage is five to seven times that of the external cartilage *An analysis* of the location and type of tear in various series of cases merely leads to confusion ' Whole ' cartilage enthusiasts report a high percentage of posterior

third lesions and usually a higher percentage of "no lesion found." The more conservative surgeons report a higher percentage of classical bucket-handle tears and lesions of the anterior one-third. The question also arises as to how extensive the tear or peripheral lesion must be to be regarded as a real lesion. Should a rent of the under surface of the posterior third of the cartilage be considered an indication for resection? Does hemorrhage into the synovial membrane adjacent to a small posterior segment rent of the periphery justify meniscectomy? Is hypermobile meniscus a valid diagnosis? Obviously there can be no unanimity of opinion in regard to these questions for this reason, the findings reported from studies of any long series of cases reflect, in general the surgeon's opinions both as to the presence of a pathologic process and indications for surgery

We freely admit that a perusal of our cases in civilian practice in the past would not reflect the true incidence of lesions of the posterior one-half of the cartilage, and that lesions in this area occupy a more important place than we have previously ascribed to them.

In some series the incidence of the hypermobile meniscus is reported as high as 9 per cent. Although we recognize the existence of such a lesion, we feel that this figure is far too high and is a subterfuge diagnosis which should be changed, in many instances to "no pathology found."

The statistics of military surgery present still another picture. Patients were frequently operated upon during the first episode thus, the pathologic process was likely to be less advanced and extensive than in those cases wherein numerous recurrences over a period of months or years had produced proportionately more severe changes in the cartilage and in the joint itself. In civilian practice, many patients will not consider surgery until a classical bucket handle tear with locking develops.

In view of these considerations, statistics are obviously worthless unless definitely qualified. In civilian practice, our conservatism in the past is demonstrated by the fact that 60 per cent of these patients exhibited a classical bucket handle tear or a lesion which could be easily visualized through an anteromedial incision.

Diagnosis.—Even the most experienced orthopedic surgeon must admit that the differential diagnosis of various types of internal derangements of the knee presents many pitfalls. The surgeon who can keep his diagnostic error within the limits of 10 to 20 per cent is a particularly astute diagnostician. It does not necessarily follow however that surgery for suspected lesions of the semilunar cartilages should accomplish little or nothing in 10 to 20 per cent of the cases. On exploration of a knee joint with the expectation of finding a classical bucket handle tear one need not have regret on finding a normal cartilage if the existing changes are sufficient to indicate arthrotomy One should feel chagrined, however following a diagnosis of ruptured cartilage, to expose a relatively normal joint, or pathologic changes of such minor degree that surgery has not been worth while. Under these circumstances, a diagnosis of hypermobile cartilage, or hypertrophy of the fat pad is frequently resorted to as a subterfuge to cover an inadequate preoperative history and examination. On occasion even the most conscientious and expert surgeon will find himself in this predicament Such errors repeated too often however are inexcusable

The status of the ligaments and the presence or absence of other bone and joint changes must be determined and one must be aware of the periarticular lesions which may produce the symptoms of a disturbance of a semilunar cartilage To avoid errors in diagnosis, one should reverse the usual process of concentrating the diagnostic studies on the most likely lesion, i e., a semilunar cartilage A patient with indefinite symptoms of internal derangement should be first examined with the idea of eliminating all of the other causes of internal derangement By this process, fewer errors in diagnosis will be made

In the presence of a definitely locked cartilage, the history reveals a series of episodes of relatively minor significance and frequently without any previous episodes of true locking Thus, it is apparent that meniscal lesions may be progressive The initial trauma probably is confined to the rear compartment, causing a small rent, with successive injuries, this gradually extends to the central or anterior portion eventually producing a typical bucket handle tear A degeneration in the meniscus secondary to the previous trauma probably is related to this pattern and to the ease of occurrence of the final lesion. Peripheral posterior tears may create a mobility of this portion of the cartilage which makes it more susceptible to impingement between the tibia and femur

The reverse of this process can be true, viz. the first episode may be the most severe, the symptoms becoming less severe and the reaction less with each recurrence of locking. Some of these are complete bucket handle tears displaced into the intercondylar notch with each episode, the rent anteriorly and posteriorly lengthens out until there is little or no impingement of the cartilage between the femur and the tibia In others, flap tears are absorbed The extreme anterior tears are locked in less flexion than those near the collateral ligaments.

Presuming that all of the related lesions have been eliminated the syndromes associated with lesions of the semilunar cartilages may be divided into two large groups, namely those clearly diagnostic with locking, and those of a more indefinite nature These two groups are approximately equal. The first group requires little discussion, the classical textbook description holds true. Real locking, however should not be considered pathognomonic of a classical bucket handle tear Other disturbances (intra-articular tumors, a pedunculated flap from the anterior cruciate ligament interposed between the condyles, or pedunculated loose bodies) may give rise to these same symptoms. In the presence of true locking however even though the diagnosis has not been correct, surgery is certainly advisable The error lies in failure to distinguish true locking from pseudolocking This error is most likely in the presence of acute lesions, wherein hemorrhages about the posterior capsule or about the internal lateral ligament may preclude complete extension until the reaction has partially subsided This explains the necessity of the preliminary treatment for synovitis (p 235) in acute lesions. Moreover true locking may be unrecognized unless the injured knee is compared with the opposite knee With 5 or 10 degrees of recurvatum a locking at 180 degrees represents a 5- or 10-degree deficit in normal extension

Military experience added materially to our knowledge of the group of indefinite semilunar syndromes, as exemplified by the patient who presents himself with a series of numerous episodes referable to the knee, frequently asso-

ciated with brief periods of disability and increase in synovial fluid, without definite evidence of locking The patient often describes a sense of 'giving away' or reports having noticed snaps clicks, catches, or jerks. Or, the symptoms may be even more vague namely recurrent episodes of pain and slight swelling of the knee following excessive activity associated with anterior joint tenderness but no true locking nor temporary joint symptoms of a snapping or clicking nature In this group even the most astute diagnostician may resort to exploration under the diagnosis of 'internal derangement type undetermined.'

Smillie points out the more predominant symptomatic and clinical features which should be of value in the differential diagnosis a sense of 'giving away' effusion, status of the quadriceps muscle areas of tenderness reproduction of the click or catch.

A sensation of 'giving away' alone has little diagnostic significance, since it may accompany a number of disturbances of the knee joint, particularly loose bodies, chondromalacia of the patella and laxity of the joint from injury or from quadriceps insufficiency Smillie observes that this symptom is most often experienced on simple flexion movements of the knee, as on walking up and down the stairs, whereas the lesions of the posterior portion of the cartilage are more likely to manifest themselves on rotary movements of the knee in the latter group, the patient frequently volunteers the information that the sensation of "giving away" was associated with a feeling of subluxation of the joint.

Effusion is primarily a finding of negative diagnostic value i e., the presence of effusion merely means that some irritative lesion exists in the joint. The absence of effusion during all of a series of indefinite episodes however practically eliminates the semilunar cartilages as the source of the pathologic process.

Quadriceps atrophy is of no particular diagnostic importance aside from the fact that it points to a chronically recurrent disability the most common cause among the more indefinite entities being lesions of the cartilage.

The finding of points of tenderness in the anterior compartment and in the region of the internal lateral ligament is of some value. This tenderness is of more significance if confined to the region of the attachment of the posterior horn.

Palpation of a suspected joint during motion may elicit more definite information. Inaudible clicks, snaps, or catches may be detected by palpation. The exact area of the clicking sensation should be determined. The clicking sensations are most often associated with the patella or the quadriceps mechanism. In the majority the clicks are located by having the patient do a full knee bend, the clicks usually being elicited as the knee is extended between 110 and 160 degrees. In contrast, in the McMurray test, the clicks associated with lesions of the posterior rim of the cartilage occur between complete flexion and 90 degrees. *The McMurray sign* With the patient in the supine position and the knee and hip acutely flexed, one hand palpates the posteromedial margin of the joint, while the other grasps the foot. While the knee remains completely flexed, the leg is externally rotated to the limit then slowly extended. Conversely the lateral cartilage is checked by acute internal rotation of the leg As the femur passes over the rent in the cartilage, the click may be audible or palpable

For examination of the anterior segment, Smillie varies the McMurray test by having the patient stand and perform essentially the same rotary movements of the joint through a range of 180 degrees to 90 degrees, thus bringing the anterior portion of the cartilage under pressure

An additional test, called the grinding test " has been described by Apley With the patient lying on his face, the affected knee is flexed to 90 degrees, and the thigh is fixed against the examining table The foot and leg are then pulled upward distracting the joint. Next, the knee is rotated, placing a torsion strain upon the ligaments. If ligamentous tears are present, pain is produced. Next, with the knee and leg in the same position, pressure and rotary motion are made downward upon the leg and foot as the joint is slowly flexed and extended. Pain will be elicited if the meniscus is torn or any loose body lies across the joint line. Although these tests cannot be considered pathognomonic they are sufficiently useful to include in a routine examination of the knee, and may perhaps add considerable evidence to the diagnosis of posterior lesions

A diagnosis of rupture of the external semilunar cartilage presents the same difficulties as the more indefinite lesions of the medial cartilage except that these features are relatively constant for all lesions of the external semilunar cartilage. True locking seldom occurs from lesions on the lateral side If lock ing does occur it usually represents practically a complete avulsion of the entire lateral cartilage. The smaller longitudinal rents are relatively silent. Peripheral tears are usually restricted to the posterior third more common is a transverse rent at the anterior and middle third (p 238) Obviously this latter group would be expected to produce rather indefinite symptoms. Curiously the symptoms of lesions of the lateral cartilage frequently lead one to believe that the tear is on the medial side Tenderness and pain immediately adjacent to the patellar tendon on its medial aspect are often associated In general, however much the same diagnostic routine is carried out

In our experience, pneumoroentgenography as a means of diagnosis has been of little value. We have found that, ordinarily lesions which can be visual ized by pneumoroentgenography can be diagnosed clinically i e., those with a gross or obvious classical bucket handle tear In the remainder we have never been able to arrive at a proper interpretation of the roentgenograms with any measure of accuracy The technic of this procedure is described on p 133

Conservative Treatment

Whether healing of the semilunar cartilages will or will not take place depends upon the type of tear in the cartilage and the subsequent treatment. In a series of experiments on healing of peripheral attachments and longitudinal or transverse incisions in the internal semilunar cartilages, King made the following observations

' 1 Tears which are limited to the semilunar cartilage probably never heal

' 2. A torn meniscus can be healed by connective tissue if the tear com municates with the synovial membrane laterally

3 A complete transverse or oblique tear results in some separation of the fragments, but the intervening space fills in with connective tissue arising

from the synovial membrane. This connective tissue is quite firm in three weeks, which suggests the length of time necessary for complete fixation in these cases.

"4. If the meniscus is partially torn from its peripheral attachment, it heals in normal anatomical position without difficulty."

These experiments correspond to clinical observations regarding healing. Unfortunately, the vast majority of tears take place in an area wherein spontaneous healing cannot be expected. Unquestionably some of the minor rips in the periphery adjacent to the synovium in the capsule will heal. Oblique or transverse tears seldom heal since the tear rarely extends from the concave through the convex side for a sufficient distance to invade an area of adequate vascularity. As a rule, conservative measures are of only temporary value and the derangement may be expected to recur. Rarely the symptoms may eventually be relieved if the defect in the cartilage or the displaced fragment is absorbed. On the other hand, the joint may be irreparably damaged if surgical removal is indefinitely delayed.

Conservative treatment is justified under two circumstances:

1. In the first acute episode wherein the diagnosis of ruptured cartilage is obscured by the secondary manifestations of the trauma; even after the acute reaction subsides, the diagnosis still may be in doubt.

2. When the associated lesions, such as tears of the internal lateral ligament or the cruciate ligament, necessitate immobilization and the joint is not locked. In these cases, surgery should be delayed until the acute reaction subsides and the rehabilitation of the extremity is complete. Thereafter the cartilage may be removed if this procedure is still indicated.

Conservative treatment is essentially the same as that outlined for acute synovitis (p. 235) with one exception. After the acute reaction subsides, the knee is extended (not hyperextended) and immobilized in an ambulatory plaster cast from the ankle to the groin (p. 34). To prevent the lower end of the cast from impinging upon the tendo achillis, a two-inch strip of adhesive tape is placed longitudinally on each side of the upper third of the thigh and allowed to extend six inches below the ankle. As the plaster bandages are applied, the free ends are turned proximally and incorporated in the cast. The extremity should remain in the cast for a period of four to six weeks. During this time, walking is encouraged, and the patient is instructed in straight leg raising exercises, as well as other quadriceps exercises to maintain the strength of the quadriceps mechanism.

Manual Reduction of Semilunar Cartilages.—This procedure is employed as a palliative measure after the primary injury or following repeated displacements with locking of the joint. If the patient will cooperate, an anesthetic is unnecessary. Once true locking recurs, obviously healing cannot be expected. Consequently the *manual reduction of a dislocated semilunar cartilage* is only a temporary measure to relieve pain and allow the reaction of the joint to subside prior to surgery.

TECHNIC OF MANUAL REDUCTION.—With the knee fully flexed, the tibia is grasped at the ankle and rocked laterally on the femur in an attempt to free the cartilage from its impingement. For reduction of a medial cartilage, the tibia is next abducted and internally rotated or, for an external semilunar

cartilage it is adducted and externally rotated The joint is then slowly extended, though extension should not be forced The patient's ability to extend the knee voluntarily and completely is usually regarded as an indication of reduction this is not an infallible sign however as the cartilage may be displaced into the intercondylar notch the rent in the cartilage being extended anteriorly so that impingement between the condyles is slight After reduction is accomplished or the cartilage has been displaced the operator usually will feel a definite slipping or snapping within the joint The most dependable sign of reduction however is still the patient's ability to extend the knee and the relief of symptoms.

After Treatment —Rest is enforced for a sufficient number of days to allow the reaction in the joint to subside to some extent In most cases continued conservative therapy is not warranted

Excision of Semilunar Cartilages

Indication for Excision.—Arthrotomy of the knee and removal of the semilunar cartilage is warranted under these conditions

1 Initial lesions which present all the signs and symptoms of a classical bucket handle tear the mesial section being impinged between the condyles The remainder of the initial lesions, whether the first episode is of a minor consequence or is attended by an acute hemarthrosis, should be given the benefit of conservative therapy Further in a large proportion of this group the diagnosis is obscure.

2 After the first recurrent episode following an initial lesion surgery is warranted, whether locking is or is not present provided one is relatively certain of the diagnosis.

Exploratory arthrotomy is indicated if the diagnosis of internal semilunar cartilage is obscure yet is the most probable and likely cause of the disability Even if the most likely diagnosis is rupture of the semilunar cartilage, a surgeon should not open the joint with the preconceived idea that, regardless, he is going to remove an internal semilunar cartilage that if the anterior compartment does not contain sufficient pathologic change probably the posterior portion will do so It is true that some of the posterior lesions cannot be visualized until the posterior limb of the cartilage is mobilized or actually removed, and the under surface is examined. We believe that the routine practice of removing the entire semilunar cartilage through an anterior incision alone is likely to lead to removal of too many normal cartilages We have no quarrel with the experts who have had vast military experience and consequently have acquired both diagnostic acumen and surgical skill in excision of the entire cartilage through one anterior incision. From our experience in the last war however this was bad teaching for the younger group of orthopedic surgeons. One of us, who had an opportunity of reviewing a rather extensive series of meniscectomies in the Army Air Force, observed that this practice among the less experienced young orthopedic surgeons led to the removal of a number of practically normal semilunar cartilages. Exploration of the anterior compartment is probably a better procedure if no lesion is found, the posterior compartment may be explored through a Henderson incision

After being unable to locate any definite pathologic change in either the anterior or posteromedial compartments, we have resorted to an incision on the opposite side, before the true nature of the lesion was determined. An experience of this sort gives one a slightly red face but a clear conscience.

Theoretically, there is some contraindication to operating upon a knee during an acute episode *Practically, even despite an extensive hemarthrosis,* we have noticed no particular deleterious effects or prolongation of convalescence. The majority of ruptured semilunar cartilages observed in civilian life have already reached the state wherein the most recent episode will produce only a slight reaction Ordinarily, in the first acute episodes attended by hemarthrosis, at least two to four days elapse before the diagnosis is definitely established. In the presence of an unusual reaction, surgery should be delayed.

Whole versus Partial Excision.—With rare exception, the orthopedic surgeons who read this book will subscribe in general to its contents. Herein we depart from the consensus, but we do not stand entirely alone In military surgery it was more or less mandatory that the entire semilunar cartilage be *removed. With this, we agree In civilian practice, we depart from this rule* under the following conditions (a) only the mesial segment of a classical bucket handle tear is removed (b) local excision suffices for the small pedunculated flaps, or L-shaped tears, or for a localized area wherein the concave edge of the cartilage is frayed or shredded. The advantages of such a procedure are as follows

1. A minimum amount of surgery and consequently a minimum amount of trauma to the joint is necessary
2. With the exception of the exposure, surgery is carried out through an avascular portion of the knee joint consequently postoperative hemarthrosis and reaction are slight, and only a small number of raw edges remain to heal.
3. *Convalescence is rapid and attended by fewer complications, such as* prolonged synovitis and effusion.

It is possible also that the residual peripheral portion of the cartilage may serve some future function. This, however is not a particular advantage.

The principal disadvantage of this method lies in the fact that more than one rent may be present in the cartilage If so the second rent will be in the posterior residual peripheral portion and cannot be visualized. Advocates of resection of the whole cartilage make much of this point, i.e., they report having removed a substantial number of residual posterior horns at a second operation. Actually when statistics are cited these constitute only a small percentage of internal derangements. We recognize this prime disadvantage, *but we feel that it is often outweighed by the advantages listed above.*

We feel that the entire semilunar cartilage should be removed for all other forms of traumatic lesions of the cartilages, i.e., for those of the posterior or middle portion of the cartilage, and for all peripheral separations or avulsions.

We can see no justification for any halfway measures between excision of the torn segment and excision of the whole cartilage. Excision of only the anterior two-thirds of the cartilage combines the worst disadvantages of both methods, and adds a few special ones. The posterior segment represents one-third of the peripheral attachment consequently it will probably move around,

eventually becoming trapped between the condyles of the tibia and femur At the junction of the resected peripheral portion with the intact posterior third, attempts at regeneration will present an irregular weak point

Associated pathology may cause as much or more disability than the meniscal lesion. Of 1,132 cases reviewed in the Army Air Forces' report, localized areas of chondromalacia of the patella or femur were present in 10 per cent, diffuse traumatic arthritis in 4 3 per cent, osteochondritis dissecans in 2.4 per cent, loose bodies of idiopathic origin in 2.2 per cent, and ruptures of the ligamentous structures in 4.3 per cent.

A sufficient exposure should be made to visualize the following structures anterior two-thirds of the medial semilunar cartilage, the anterior third of the lateral cartilage anterior portion and attachment of the cruciate ligaments, the under surface of the patella, and the articular surface of the femoral condyles. A two-inch anteromedial incision is adequate

In making incisions for removal of the internal semilunar cartilages, one should keep in mind the saphenous nerve, which passes along the medial aspect of the knee behind the sartorius muscle, then pierces the fascia lata between the tendons of the sartorius and gracilis muscles, becoming subcutaneous on the medial aspect of the leg On the inner aspect of the knee, a large infra patellar branch is given off from the nerve and distributed to the skin over the anteromedial aspect. Although severance of this nerve is not of serious consequence, it should, nevertheless, be protected by close adherence to the line of the incision to be described subsequently

Meniscectomy should be performed under a tourniquet so that pathology can be properly visualized. Constant sponging in the joint not only slows up the operation but unnecessarily bruises the joint surfaces. Prior to closure however the tourniquet should be released and hemorrhage controlled.

If desired, the technic described below may be carried out through one skin incision (Bosworth, or Cave incisions), and thereafter by essentially the same deep dissection through two incisions in the capsule

Special instruments which aid in resection of the semilunar cartilages are the Martin clamp and one of the cartilage knives devised by Freiberg Lowe and Breck, or Smillie.

Excision of the Entire Medial Cartilage.—The skin, fascia, and capsule are incised, beginning just medial to the middle of the patella, and passing downward and parallel with the lower half of the patella and patellar tendon a distance of two inches. At the proximal end of the wound the synovial membrane is grasped by two small hemostats, one of which is held by the operator and the other by an assistant while traction is maintained on these structures, a small opening is made into the joint with a scalpel. If there is irritation within the joint, fluid will escape immediately The opening in the capsule and synovium are enlarged distally and all excess fluid is gently sponged from the joint. The entire joint is systematically examined in the following order the medial semilunar cartilage, the articular surface of the patella, femur and tibia, the cruciate ligaments, the anterior tibial spine, the anterior third of the lateral cartilage, and finally, the suprapatellar pouch is examined for loose bodies. Through a relatively small incision much of the suprapatellar pouch cannot be visualized, particularly the lateral portion. For this reason, a digital exam

ination is made a fresh sterile glove being worn If a classical bucket-handle tear is present, the technic is carried out as described below otherwise the entire cartilage is removed

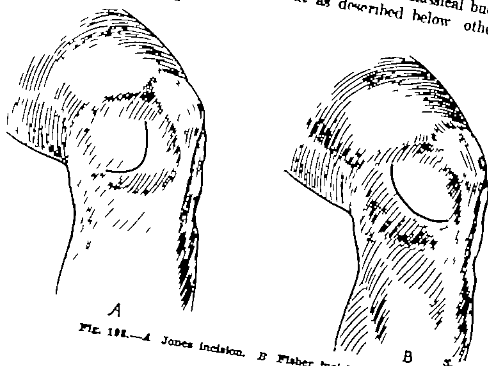
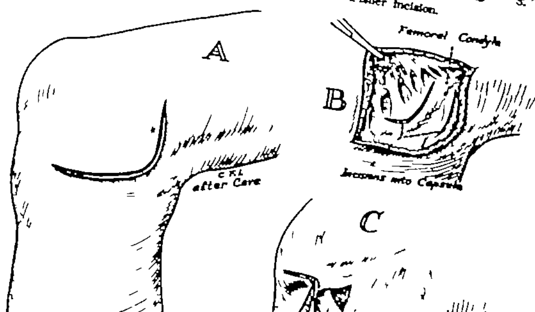


Fig. 198.—A Jones incision. B Fisher incision.



The central portion of the periphery of the cartilage is next dissected free with a straight cartilage knife or an old fashioned single unit scalpel (scalpels with removable blades should never be used in the depths of the knee joint, the brittle, removable blade may snap in two, and the fragment may be rather difficult to retrieve) In freeing the central, peripheral portion of the cartilage, care should, of course be exercised to avoid cutting the internal lateral ligament. This portion of the dissection is not particularly difficult, although the space is limited A small hemostat is inserted through the anterior incision between the medial condyle and the internal lateral ligament, pointing posteromedially, to facilitate the location of the posteromedial (Henderson) incision The latter is approximately two inches long and parallel and slightly posterior to the internal lateral ligament The fascia, capsule, and synovium are incised in line with the skin incision After mobilization of the posterocentral portion, the anterior and central portions of the semilunar cartilages may be withdrawn to the posterior incision. After mobilization of the posterior limb and severance of the mesial attachment, the entire cartilage is delivered from the posterior incision The joint is thoroughly cleansed and inspected, and small tags or remnants of the cartilage are excised. In suturing the incisions, the raw edges of the synovium are everted by running mattress stitches thus, the amount of catgut within the joint is minimized.

After Treatment.—Pads are compressed about the knee with an elastic bandage. The latter is snugly wrapped from the base of the toes to well above the knee. The temporary use of a posterior gutter splint for three or four days is optional. The entire limb should be elevated for the first few days. Quadriceps muscle exercises should be commenced on the first postoperative day, the technic having been taught the patient prior to the operation As soon as the patient has mastered this exercise, straight leg raising should be encouraged This method of retaining and strengthening the quadriceps mechanism should be carried out in a systematic manner every hour on the hour when the patient is awake. At the end of ten days, if there is no effusion or undue reaction mobilization of the joint is begun The return of function in the joint is in direct proportion to the return of strength and tone of the quadriceps and hamstring muscles. An accurate check should be kept on the musculature of the leg and weight-bearing begun only after good tone and strength have been restored in the quadriceps and effusion in the joint has entirely disappeared. This is usually two weeks. The stitches may be withdrawn from the tenth to the fourteenth day The patient should be encouraged to continue weight resistant exercises of the extremity until recovery is complete Weights and pulleys are ideal or a sandbag hung across the dorsum of the foot in the manner of a saddle bag may suffice for these exercises. In the beginning about two pounds of weight should be used and this should be increased concomitantly with the number of times the weight is lifted, until eventually the patient can extend the knee fifty times against ten pounds of resistance. A full return of muscle power is evident when, on complete active extension of the knee, the vastus medialis muscle stands up prominently and compares favorably with the muscle on the opposite extremity

Excision of Mesial Segment of Bucket-Handle Tear—The knee joint is exposed by the same anteromedial incision described above The nature of the

defect in the cartilage is obvious if a classical bucket handle tear is displaced into the intercondylar notch. Only the detached or mesial segment is removed. The latter is severed transversely at its junction with the peripheral segment anteriorly, grasped with a Martin clamp, and pulled forward. With a cartilage knife directed posteriorly in the intercondylar notch, the posterior segment is severed at its attachment to the posterior horn of the cartilage, under direct vision. As the displaced segment usually consists of less than one-half the width of the cartilage, the peripheral portion may remain with impunity, and perhaps continue to serve some function. Small, flat tears, frayed edges, or incomplete rents may be treated by local excision

After Treatment.—See above.

Excision of the Entire Cartilage Through Anterior Incision.—The joint is exposed by the anteromedial incision described above. Similarily, the anterior limb of the cartilage is mobilized with a scalpel, grasped with a Martin clamp and retracted toward the center of the joint. With a straight or slightly curved cartilage knife, the central portion of the periphery of the cartilage is dissected free Mobilization of the posterior limb is the most difficult portion of the dissection, and requires a cartilage knife with the proper concavity (Fig 76) While the surgeon maintains constant but gentle traction on the cartilage in the midline of the joint, the curved cartilage knife is worked around the peripheral portion of the posterior horn. Excessive traction may rupture the cartilage and allow it to retract posteriorly, thus necessitating a posteromedial incision. Considerable patience, experience, and dexterity is necessary to accomplish this portion of the dissection cleanly and completely As dissection progresses, the cartilage may be displaced into the intercondylar notch In this event, the division is completed by passing the cartilage knife in the intercondylar notch and finally dividing the mesial attachment of the posterior horn under direct vision

Smillie states that if the posterior horn of the cartilage is practically intact, this portion of the dissection may be difficult. In these cases, he suggests a reversal of the final two steps in the procedure, namely, the mesial segment of the posterior horn is divided through the intercondylar notch under direct vision, followed by mobilization of the posterior periphery If the joint is relatively tight, it may be rather difficult to pass the cartilage knife around the medial edge of the condyle and satisfactorily accomplish dissection. In this case, one always has recourse to a separate incision.

After Treatment.—See above

Excision of the Lateral Cartilage.—As mentioned above, the signs and symptoms of injury to the lateral cartilage are less definite locking is less common, and clicking or snapping is frequently more audible or palpable on the lateral side than on the medial side

The external cartilage may be more easily resected in its entirety through an anterior incision than the medial cartilage. The technic is the same In excision of the lateral cartilage, the popliteus tendon as well as the ligaments must be protected

The majority of patients who have an offending cartilage of the knee resected before secondary changes have taken place within the joint may anticipate excellent results. In a series of 664 meniscectomies, Lipscomb and Henderson

reported that 75 per cent of their patients obtained relatively normal joints. This is in considerable contrast to the military figures where so many extraneous considerations complicated a proper appraisal

Postoperative Complications.—The two most common immediate postoperative complications which affect the end result are an extensive hemarthrosis and postoperative chronic synovitis. The first requires evacuation by aspiration until the hemarthrosis is reduced to a point which permits the synovial lining to eliminate the residual debris.

The mild, transient, chronic synovitis incident to too early and too much knee motion an inadequate quadriceps and too early weight bearing has been previously discussed (p 235) This type of synovitis should not be confused with a more persistent type which does not yield readily to ordinary therapy Apparently factors other than the trauma of surgery enter into the etiology Because of the relatively routine practice of administering penicillin or the sulfa drugs prophylactically in most major surgery, true pyogenic postoperative infections of the joint are rare There appears to be, however a group of infections which are maintained at a low grade by the administration of the penicillin. Frequently, these patients have a mild fever and signs of local inflammation which continue during the postoperative period and are attributed to postoperative reaction A low-grade infection persists leading to a chronic synovitis before the true pathology is recognized. In this chronic stage the sedimentation rate is usually increased, and a relatively cloudy synovial fluid may be aspirated, perhaps with some of the elements of the blood in the transudate and effusion. A comparison of the two knees merely shows a rather boggy, proliferative synovitis associated with considerable fluid in the joint on the affected side. Repeated aspirations are only followed by reformation of the fluid until the joint remains more or less moderately distended. Enforced rest has no effect on the synovitis. During the war, one of us worked out a satisfactory form of conservative treatment for this condition (Chapter XIII)

Regeneration of Cartilage After Excision

In an endeavor to ascertain the functional roles of the semilunar cartilages, King conducted experiments on the knees of dogs, removing the cartilages partially or completely and examining these joints at intervals thereafter His conclusions were as follows When the internal semilunar cartilage of a dog s knee is removed, the defect is filled by an ingrowth of fibrous tissue from the synovial membrane which is grossly indistinguishable from normal fibrocartilage. Despite this replacement, articular hyaline cartilage degenerates to a degree roughly proportionate to the size of the segment removed. These changes are more pronounced in older dogs than in puppies.

Bazzocchi carried out similar experiments on rabbits and found that regeneration of the semilunar cartilage was almost complete, both grossly and microscopically He states, however that regeneration of the semilunar cartilages in man is not so well advanced as in animals, being more fibrous than cartilaginous. He found arthritic changes even five months after removal of the cartilages.

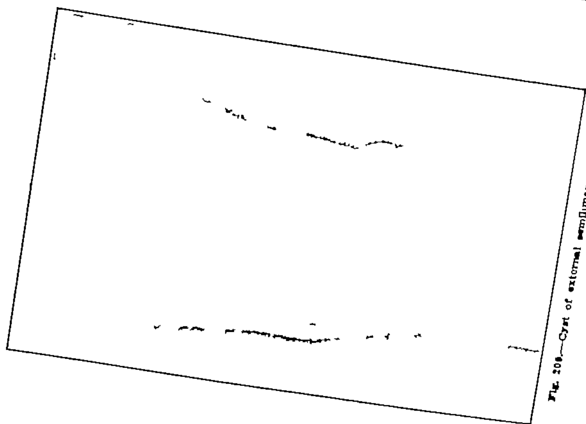


Fig. 200.—Cyst of external semilunar cartilage

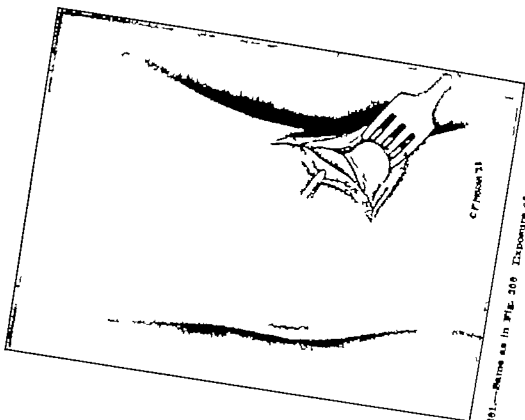


Fig. 201.—Same as in Fig. 200 Exposure of cyst by curved incision.

Bruce and Walmsley observed that four days after excision of the menisci a proliferation of fibroblasts takes place beneath the surface of the synovial membrane at the level of the joint. At the end of the third week the proliferation from the tibia fused with a similar proliferation from the femur to form a new meniscus.

Smillie in 1944 reported five cases wherein at subsequent operations complete regeneration of a totally excised meniscus had taken place. He found seven recorded cases. The fibrocartilaginous meniscus was replaced by a glistening, fibrous tissue ring which was whiter than the normal meniscus but in gross appearance and shape had much the same form as the normal structure. The attachment to the capsule however was dense and no definite line of cleavage was present. On cross section, the new meniscus was thinner and narrower lacking the normal wedge or triangular shape. Microscopic examination showed only fibrous tissue cells, no fibrocartilage was found.

He further reports cases of regeneration of an anterior half or two-thirds of a partially removed meniscus, the union of the new to the old portion of the meniscus being a point of weakness and potential injury. He therefore believes that total excision is always preferable to partial excision in that the reproduction and regeneration of the cartilage is more perfect and thus it is better able to perform its original function.

We too have observed these attempts at regeneration. In our experience, however, the replica is rather frail as compared with the robust original meniscus, and its functions are probably proportionate.

Discoid External Semilunar Cartilage (Snapping Knee)

The fetal status of the semilunar cartilages is represented by a fibrocartilaginous expansion which completely covers the area from the periphery of the joint to the mesial portion and consequently interposes between the articular surfaces of the tibia and femur. Some developmental error precludes the absorption of the central expansion which characterizes the normal, anatomic adult structure. Probably this lesion is more common than clinical statistics indicate. Undoubtedly many discoid lesions cause no symptoms unless subjected to trauma, which leads to symptoms of internal derangement. Usually this lesion is discovered quite by accident, and is not anticipated preoperatively. On occasion however the diagnosis may be made preoperatively. The chief manifestation is a loud snap on flexion and extension of the knee, perhaps attended by minor sensations of catching on flexion and extension of the joint. This phenomenon is unaccompanied by any of the secondary manifestations of internal derangement such as effusion. Ordinarily the disability is not sufficiently severe to warrant surgery unless a traumatic lesion is superimposed. We have removed the external semilunar cartilage bilaterally from one patient wherein the snapping sound was sufficiently loud to cause him extreme embarrassment. The treatment consists of excision of the entire cartilage. The technic is similar to that described for traumatic lesions of the semilunar cartilages. Recovery should be uneventful.

Cysts of the Semilunar Cartilages

Cysts of the semilunar cartilages develop far more frequently in the external cartilage usually following injury and are manifested by tumefaction

and pain. The tumor is always palpable on the lateral aspect of the joint, immediately anterior to and above the head of the fibula, and is fixed to the tibia, moving only when the tibia moves. The cyst of average size is characteristically most prominent on extension and less prominent on flexion; the smaller lesions may disappear within the joint on flexion. On incision, the mass will be found to contain a clear, viscid, gelatinous material. In some cases, the cyst is multilocular. Treatment consists of removal. We have employed aspiration only once, in a patient who refused operation. The contents of the cyst were evacuated with a large gauge needle; symptoms subsided and have not recurred. Such a procedure is not likely to be uniformly successful.

The cyst and cartilage are exposed by an anterior and a posterolateral (Henderson) incision (p. 144) or by the Cave or Bosworth incision. The entire cartilage and cyst are removed according to the technic described above for traumatic lesions of the menisci (p. 245).

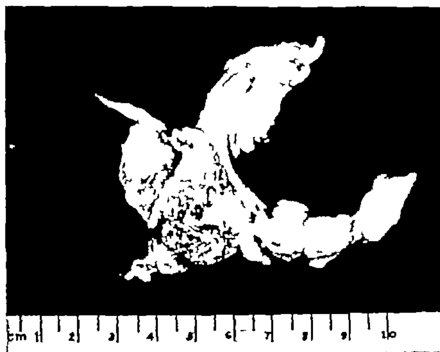


Fig. 202.—Gross specimen of a cyst of semilunar cartilage.

Excision of Cartilage of the Temporomandibular Joint

Aside from the knee, the only joint wherein a fibrocartilaginous derangement occurs is the temporomandibular articulation. On motion, there is a snapping or popping sound. Excision of the cartilage is not warranted unless pain as a result of traumatic arthritis is severe.

Technic.—An incision is made one-half inch anterior to the external auditory meatus and extended along the zygomatic process for one and one-half inches. Dissection is carried down to the zygoma, thence to the capsule of the temporomandibular joint. If this does not afford an adequate operative field, the skin incision is prolonged downward one inch at a right angle from its beginning. The ascending branch of the facial nerve which lies just anterior to the external auditory meatus must be carefully avoided. (Fig. 203.)

The capsule is incised transversely, and the articular disc is dissected free from its attachments to the capsule and to the tendon of the pterygoideus externus muscle anteriorly The fibrocartilage is removed in toto, with a small scalpel In closure of the skin the cosmetic result should be borne in mind

RUPTURES OF LIGAMENTS OF THE KNEE

The status of operative repair of the ligamentous structures of the knee would seem to be controversial The results of these procedures, interpreted in the light of their efficiency in the military services, are conducive to an attitude of pessimism The military statistics are apparently contradictory to previous reports of a fairly high percentage of stable knees, and even a few brilliant results in athletes who were able to return to their careers as football players. An analysis of both the enthusiastic and the pessimistic reports reveals a lack of sufficient qualifications of the end results in the first group, and a lack of understanding of the scope and limits of ligamentous repair in the second group Somewhere between these two extremes, the truth must lie. Campbell's early reports from this clinic, of excellent, good, fair, or poor results, would be interpreted in the military services as fair poor or failures From our own military and civilian experience we shall try to interpret both sides of this picture properly and impartially

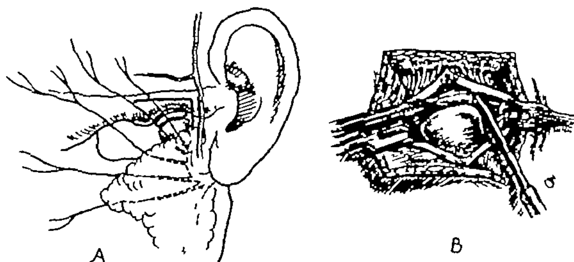


Fig 203.—Removal of articular disc, or meniscus from *temporomandibular joint.* *A* Line of skin incision. The posterior end of longitudinal incision along zygoma is extended downward with care to avoid facial nerve and parotid gland. *B* Exposure of joint and removal of disc.

A consideration of the indications, limitations, and end results of any ligamentous repair necessitates detailed discussion The normal function of a joint, the average stability, the mechanism of injury and the inter relation of the stabilizing structures have been previously discussed (p 228)

The muscles are the one active element which provides a means of increase in stability of the joint without resorting to surgery Proper stability and function of the joint are impossible without adequate quadriceps, hamstring and gastrocnemius control. No operative reconstruction should be undertaken in an old ligamentous injury until a prolonged and sedulous effort has been made to restore normal muscle power Nonweight bearing and weight resisting exer

cases should be carried out for several months. Frequently, it will be found that surgery is no longer necessary. The joint still may be subjected to injuries, however, when the patient is not on guard during momentary periods of relaxation of the muscles. Following surgery it is equally as important that the muscle power for control of the knee be properly revived.

The stability which follows complete disruption of all the ligaments and the capsule in dislocation of the knee attests the possibility of satisfactory end results from efficient conservative treatment of an acute ligamentous injury. To a degree this also applies to less dramatic and isolated injuries. Herein lies the "joker." Many of these ruptures are unrecognized and are diagnosed as sprains or strains of the knee joint, or acute synovitis. Since repair of a ligament takes place rather slowly, over-enthusiastic attempts to obtain mobility and function may be expected to lead to chronically unstable knees in a fairly large number of these cases. *In the presence of acute, complete disruption of the collateral ligaments*, a high percentage of satisfactory knees may be anticipated following operative repair. This is not true of acute ruptures of the cruciate ligaments; here, for reasons explained below, surgical repair is usually neither practicable nor feasible.

Chronic ruptures of ligaments are frequently attended by a vicious cycle of disabling developments. The joint becomes unstable, allowing frequent recurrent injuries, usually of relatively minor consequence but associated with increased stretching of the ligaments. Effusion and muscle atrophy may follow, thereby making the knee more susceptible to another turn around the vicious cycle. With each episode, the articular surfaces and other joint structures are damaged to some extent, thus leading to a degenerative arthritis, the latter in itself being capable of producing major disability. Other forms of internal derangement may be associated with the primary or subsequent injuries. If such a chain of events is allowed to persist over a period of months or years, the mere reconstruction of the ligamentous structures cannot be expected to produce a satifactory knee. In contemplating reconstruction of the ligaments for old tears, all of these factors must be taken into consideration and the prognosis should be guarded. In reviewing the end result, the function of the joint must be interpreted accordingly.

Even after eliminating all the extraneous factors and considering only the mechanics of the joint after ligamentous reconstruction, one must recognize the limits of the operative procedures. Neither the normal anatomy nor function of the original set of ligaments can be restored by surgical reconstruction. This is particularly true of the cruciate ligaments. Their function is far more complex than the single, isolated functions heretofore assigned to them. Even their anatomy is relatively complex. Consequently, any structure which is utilized to replace their function is likely to be inadequate in size and strength. It is surgically impossible to duplicate their rather broad, flat attachments to the condyles of the femur. The mechanism by which these ligaments maintain their tension throughout the range of flexion is dependent upon this normal attachment and the ability of these attachments to roll the ligaments, thereby keeping one edge of the ligament continuously tense. It can be readily demonstrated at the operating table that a reconstructed anterior cruciate ligament which is attached to the condyles of the femur, yet *loose in its tunnel through*

the tibia, has considerable excursion as the knee is flexed and extended The newly reconstructed ligament is certain to stretch to the limits visualized at the operating table Improper placement of the attachments of the new ligament exaggerates this effect It can be safely stated that although some of the ligamentous reconstructions of the cruciate ligaments improve stability they cannot restore the functions of the original ligaments To a certain extent, these fundamental points are true of the lateral ligaments, though to a far less degree

In considering the indications as well as the end results, the future activities and occupation of the individual are of paramount importance One should recognize from the beginning that the newly reconstructed ligaments are capable of withstanding average activity, but are entirely inadequate, as a rule, for athletics or similar rigorous activities. The end results of the ligamentous operation must be interpreted as good fair, or bad in the light of the ability of the individual to earn a living in an average occupation not as an athlete.

Rupture of the Lateral Ligaments

In the presence of lateral instability, roentgenograms should be made to demonstrate the status of the condyles of the femur and tibia particularly in elderly individuals. Not infrequently, this lateral instability may be caused by a depressed fracture usually of the external condyle of the tibia in association with ligamentous injury In this situation the bones assume primary importance in the re-establishment of function

Abbott notes the following important points in the diagnosis of acute injuries of the lateral ligaments the patient complains of pain, not too severe immediately after injury symptoms gradually increase and eventually the knee cannot be fully extended because of muscle spasm. Tenderness is marked in the region of the tear To complete the examination local or general anesthesia may be necessary The classical test for lateral instability is carried out with the knee in complete extension this same test should be performed with the joint slightly flexed. Abduction rocking with the joint extended suggests a combined rupture of the anterior cruciate and internal lateral ligaments a stable knee in extension with abduction rocking on slight flexion isolates the injury to the internal lateral ligament The reverse of these findings, adduction rocking indicates rupture of the external lateral ligament. Combined injuries, involving the anterior cruciate ligament are further corroborated by the presence of an anterior drawer sign.

In differentiating minor rents from complete rupture roentgenograms should be made with the knee slightly flexed while an abduction or adduction force is exerted. Thereby the degree of separation of the condyles can be accurately ascertained. Further if the rent does not involve intra-articular structures (synovium or cruciate ligaments), swelling and hematoma are superficial with complete rents, these findings are accompanied by a hemarthrosis.

The diagnosis of chronic tears of the lateral ligaments follows the same pattern described above but is far simpler the reactions to the acute trauma are absent.

The most common injury to the ligaments of the knee joint is a minor interruption of the anterior fibers of the internal lateral ligament at its attach

ment to the femoral condyle (see also Pellegrini-Stieda's disease, p 277) This lesion and rents associated only with instability in the flexed position may well be treated conservatively

In the presence of complete avulsion or tear of the ligament attended by hematoma, swelling marked lateral instability in extension, and a palpable defect or roll of ligament, exploration and repair is warranted. An associated cruciate ligament injury is ordinarily not repaired. Surgery may be necessary for an injured semilunar cartilage

Complete tears or ruptures of the lateral ligaments may assume many bizarre forms, large flaps of ligament may be interposed between joint surfaces, precluding proper coaptation of the condyles (p 290) A standard technic of repair consequently is not possible Most contingencies will be met by the operative technic described below

Instability from chronic ruptures or elongation associated with recurring episodes of internal derangement, warrant repair All of the preliminary considerations previously mentioned must be properly appraised before arriving at this decision. Certainly, repair of the lateral ligaments can be undertaken with fewer mental reservations than the cruciate ligaments. With a properly selected case, adequate surgery and good muscular development, the joint should be stable in extension since the cruciate ligament is usually stretched or has been torn at the time of the original injury the joint can be expected in most instances to manifest a varying degree of lateral instability in a flexed position

Repair of Acute Ruptures of the Internal Lateral Ligament

Technic.—A longitudinal incision is made over the medial aspect of the joint, being so placed as to allow exposure of the most proximal and distal portion of the internal lateral ligament. Oblique or transverse ruptures are frequently sufficiently extensive to allow a rather thorough inspection and, if necessary excision of the internal semilunar cartilage Subsequent repair of the ruptured ligaments depends upon the nature of the rupture. Avulsions of the ligament, accompanied by a fair-sized fragment of bone, are simply repaired by reduction of the loose fragment of bone and fixation with a screw A completely detached ligament may be reattached to the bone by means of stainless steel staples, the apposing bony surfaces being first scarified. Though seldom presented, these two situations are ideal for repair More often, the tear is represented by a rather irregular shredded and frayed component on each end In this event, the repair is hardly comparable to the suture of a clean laceration of a tendon. Particular attention should be directed toward the establishment of the anterior portion of the ligament This portion normally remains relatively tense throughout the complete range of flexion. Bunnell pull-out sutures, or permanent mattress sutures of braided silk are particularly suitable During the repair trimming the edges of the ruptured ligaments to any material degree is inadvisable, as re-establishment of the continuity of the tendon may be difficult or impossible. One need not be disturbed by the rather disorderly appearance of small tags of ligaments after repair Subsequent absorption and scar tissue will smooth out the defects.

After Treatment.—The extremity is immobilized in a gutter splint, in a position slightly less than complete extension. The ligament is relatively tense

in this position and will be mechanically tight on subsequent complete extension or hyperextension. Two weeks postoperatively (three weeks postoperatively for the steel Bunnell pull-out sutures) the stitches are removed, a cast is applied from the groin to the toes, and, with the exception of early mobilization, muscle re-education is carried out as previously described (p. 249). The patient is then permitted to walk on crutches, the knee remaining in a fixed position of slight flexion. Four weeks postoperatively, walking is permitted with the extremity in a cage knee brace, muscle re-education being continued. Protection is enforced for an additional two months.

Repair of Chronic Rupture of the Internal Lateral Ligament

Numerous operations have been devised for the repair of this ligament. Many of these are extensive and too often sacrifice the support of other structures as tendons or fascia. Others create a rather small and inadequate replica of the original ligament. This is true of an operation previously reported from this clinic, wherein the fascia on the inner side of the thigh was utilized to replace the ligament; this structure is not well developed and is usually too weak to serve as a ligament.

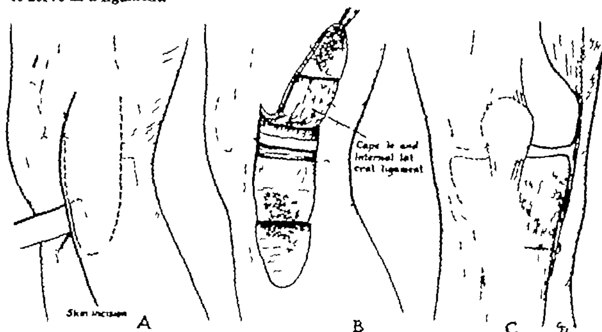


Fig. 204.—Modified Mauck operation for repair of chronic rupture of internal lateral ligament. *A*, After elevation of internal lateral ligament with its bony attachment, *B*, the ligamentous bone flap is *drawn distally as far as possible*, and *C* anchored to tibia with a screw. End of internal lateral ligament is 4-5 cm. distal to joint. Short ligament, obtained in original Mauck procedure eliminates gliding possibilities. Bone immediately distal to joint is not scarified.

In our hands, the Mauck operation has proved satisfactory. Assuming that the rent or rupture has filled in with scar tissue, but that the ligament is elongated or relaxed, the distal attachment of the ligament is replaced at the lower level to take up the slack. This is a simple procedure in contrast to some of the more complicated repairs of the internal lateral ligament.

According to Voshell, "When a tibial ligament has been stretched and relaxed, I would be inclined to use one of two methods: Mauck's tibial ligament attachment transplant, or a criss-cross fascial lacing after scarification or plication of the longitudinal fibers. In using Mauck's operation, the end of the

ligament is not where Mauck described it in his original article but is 4-5 centimeters distal to the joint The short ligament obtained according to Mauck's earlier description would seriously handicap or prevent much knee rotation and flexion by eliminating the gliding possibilities of the ligament which are dependent upon proper length

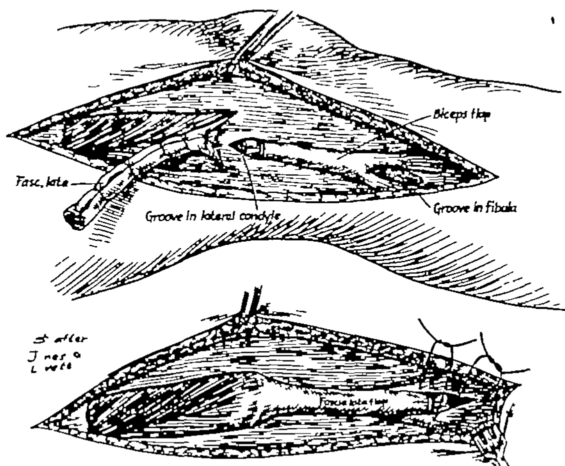


Fig 205 —Repair of external lateral ligament (Edwards) (Redrawn from Jones and Lovett Orthopedic Surgery New York, 1924, William Wood and Company)

Technic (Mauck) —A slightly curved incision, its convexity anteriorly is made on the medial aspect of the knee from the adductor tubercle of the femur to four inches below the articular surface of the tibia. The distal attachment of the internal lateral ligament is removed with a triangular section of bone, the latter being two inches long and one-half inch thick at its proximal end At the joint surface, the capsule is split upward for one inch at both the anterior and posterior margins of the bone flap providing ample exposure for removal of the internal semilunar cartilage, if necessary or the correction of any other internal derangement. The ligament and bone flap are drawn downward and the point to which the articular surface of the flap reaches is marked by a chisel cut. At this point a notch is made in the side of the tibia, forming an overhanging shelf of bone beneath which the lower end of the bone flap is mortised. The inner surface of the ligament is scarified and placed in contact with the denuded area of the tibia that the ligament may be firmly adherent to the bone when healing is complete. (Fixation is firm if a screw is inserted through the bony attachment of the distal end of the ligament.)

After Treatment.—The extremity is immobilized by a long leg cast at 150 degrees. Quadriceps setup exercises are enforced after the postoperative reaction subsides. Mobilization of the joint is begun three weeks postoperatively. Weight bearing in a cage knee brace is permissible. After the quadriceps is well developed, the knee can be extended to 180 degrees. Cultivation of muscle function by special exercises is of the utmost importance. Motion should not be forced but cultivated gradually.

Repair of Acute Rupture of the External Lateral Ligament

An isolated acute injury of the external lateral ligament, or an avulsion of the iliotibial tract from the lateral condyle of the tibia is a rather rare lesion. The technic of repair follows the same technic as outlined above for the internal lateral ligament (p. 258). A proximal extension of the Henry approach to the fibula provides adequate exposure.

Platt calls attention to the fact that adduction forces, or adduction forces associated with rotation and hyperextension may produce a definite series of findings: (1) rupture of the lateral ligament and capsule close to the tibial margin, (2) avulsion of the distal end of the lateral ligament together with the styloid process of the fibula, (3) avulsion of the biceps tendon, (4) rupture or stretching of the peroneal nerve, (5) if the injury is excessively violent, a complete dislocation of the knee joint.

Obviously in these conditions, the status of the ligaments assumes a secondary role. Of the nine cases which Platt reports, the peroneal nerve was completely ruptured in five. A peculiar finding at operation is the location of the ends of the nerve. The proximal fragment retracts together with the avulsed biceps tendon, while the distal portion of the nerve loops upward into the knee joint through a gap in the lateral capsule. The technic of repair of the peroneal nerve is described in Chapter XI. Suture of the biceps tendon follows the technics previously described in Chapter III.

Repair of Chronic Ruptures of the External Lateral Ligament

The majority of technics for repair of the internal lateral ligament are readily adaptable to the external lateral ligament; only the Edwards procedure will be described in detail.

Technic (Edwards).—The fascia lata, the tendon of the biceps, the lateral condyle of the femur and the head of the fibula are exposed through a longitudinal lateral incision. The peroneal nerve should be carefully avoided. A rectangular flap three inches long is raised from the fascia lata, its base over the femoral condyle and is folded and sutured to form a narrow tube. A flap also three inches in length, is dissected up from the biceps tendon. The area on the external condyle of the femur to which the ligament is normally attached is exposed and a cavity one-fourth inch deep and one half inch long is made in the vertical axis of the bone. A similar cavity is excavated on the head of the fibula. The biceps flap is inserted into the groove on the external condyle and held with a small staple. The flap of fascia lata is turned down, inserted into the cavity on the head of the fibula, and also maintained in position by a staple. Both flaps are fixed in position while under strong tension. A few stitches are added to assist in supporting these attachments.

After Treatment.—(See p. 258.)

RUPTURE OF THE CRUCIATE LIGAMENTS

Rupture or impairment of function of the cruciate ligaments is uncommon, as compared with that of other internal derangements of the knee The anterior cruciate ligament is injured more often than the posterior The anterior and posterior drawer signs are diagnostic. In association with injuries of the other ligaments, these signs are exaggerated.

Impairment of the cruciate ligaments is evidenced by anterior posterior instability The test of their integrity is made with the knee flexed to 90 degrees if the anterior ligament is ruptured or stretched, the tibia will glide forward on the femur, if the posterior ligament is elongated or torn, the tibia may be made to slide backward on the femur The stability should be compared with that of the unaffected knee.

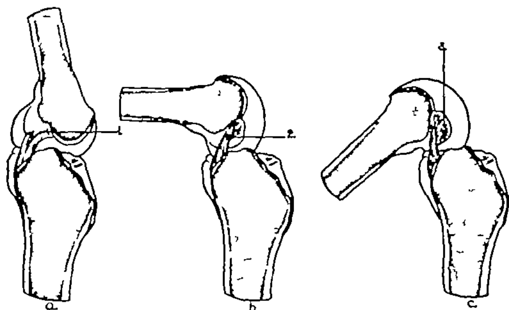


Fig. 205.—Cross section through middle of stripped joint. Note manner of attachment of posterior cruciate ligament. Some portion of ligament is taut in all positions of extension and flexion by twisting and rolling of ligament. a, Femoral attachment of ligament parallel with joint in extension. b, With partial flexion, the tension changes smoothly from posterior to anterior fibers. c In flexed position, femoral attachment of cruciate ligament is perpendicular to joint anterior cruciate ligament presents essentially same features. (From Brantigan, O C. and Voshell, A. F J Bone & Joint Surg 23 44 1941.)

Isolated injuries of the anterior cruciate ligament are far less common than those of the internal lateral ligament. Hyperextension can produce such an injury Usually however if the cruciate ligament is torn there is more than likely a partial tear or stretching of other structures. A hematoma of the popliteal space should suggest a rupture of the posterior cruciate ligament if a forceful blow was struck on the upper end of the tibia of a flexed knee. Hyper extension injuries may injure both cruciate ligaments. A blow from the inner side may rupture both cruciates and the fibular collateral and vice versa, for lateral injuries. More commonly the anterior cruciate and internal lateral ligaments are injured simultaneously We have observed fresh, incomplete avulsions of the posterior and anterior cruciate ligaments in connection with first episode injuries of the internal semilunar cartilage. In the majority of cases, by the time the knee is explored the area of rupture is partially replaced by an area of granulation tissue and pannus. The incomplete rents are not worthy of attempts at surgical repair

In civilian practice, a complete, acute rupture of an anterior or posterior cruciate ligament is not often recognized unless associated with a locking lesion of the semilunar cartilage. During military service some of us had an opportunity to explore a large number of acute injuries of the knee primarily for cartilaginous injuries, though also for ligamentous injuries It would seem that, in many cases, suture of an acute rupture of a cruciate ligament would be possible. Unfortunately the ligaments usually tear in a manner which precludes suture Complete ruptures of the ligaments, ordinarily, are not clean transverse tears, or avulsions at their attachments. Rather, the ligament is frayed, shredded, and presents a Z- or sleeve-type of rupture and elongation If arthrotomy is delayed for as long as two weeks, the ends undergo retraction and absorption precluding primary suture Further many of the complete ruptures of the cruciate ligaments are associated with complete tears of the internal collateral ligament and lesions of the medial meniscus The internal lateral ligament is usually repaired to the exclusion of the anterior cruciate ligament. Operation upon all three at one time would indeed be a major undertaking

There is, however, one injury wherein the interruption of continuity of the cruciate ligaments may be easily recognized and efficiently repaired during the acute stage, i.e. avulsion of a bony attachment Surgery is indicated if the attachment is displaced. These injuries are visualized in the roentgenograms as fractures of the tibial spine for the anterior ligament, and an avulsion fracture of the posterior rim of the tibial condyle for the posterior ligament Avulsions of the ligaments from their femoral attachments do occur but without a substantial segment of bone.

An isolated repair of a chronic rupture of the cruciate ligaments is seldom indicated. An increased drawer sign and symptoms associated with moderate anteroposterior instability are ordinarily not sufficient indication for a procedure of this magnitude. The relationship of the various ligaments of the knee is demonstrated by this example at arthrotomy a complete chronic rupture of an anterior cruciate ligament may be demonstrated in a knee which preoperatively manifested little or no clinical findings indicative of this pathology Thus, it becomes apparent that if the remainder of the ligamentous structures are relatively intact and the muscles controlling the joint are well developed, the loss of one cruciate ligament is often compatible with relatively normal function of the joint. The formulation of the indication for an isolated repair of a cruciate ligament is difficult and even questionable Voshell makes the following statement

In the presence of a good tibial collateral ligament and well trained mus[illegible] structures the anterior cruciate ligament need not be repaired except [illegible] unusual economic or athletic situations even then there would be some qu[illegible] as to whether the after results would almost equally interfere with the [illegible] function. The tibial collateral ligament is the most important single li[illegible] but even it is dependent upon the efficiency of one or both cruciates, [illegible] the posterior

A marked anterior drawer sign, associated with severe lateral [illegible] instability of the joint and recurrent traumatic episodes, does [illegible] proportions. Frequently there is a marked excursion with sublux[illegible] joint which the patient can voluntarily perform. Should the ant[illegible] ligament or the internal lateral ligament, or both, be repaired? [illegible] favors repair of the internal lateral ligament alone provided [illegible]

cruciate ligament is intact. From this type of repair however one should not expect complete stabilization of the joint particularly in flexion with the muscles relaxed. If, after a reasonable period of convalescence stability of the joint is still inadequate to prevent excessive motion repair of the anterior cruciate ligament may be undertaken This is about the only circumstance wherein reconstruction of the anterior cruciate ligament is indicated

Repair of Acute Rupture of the Cruciate Ligaments

Successful suture of the central portion of a cruciate ligament has been reported, but ordinarily it is not possible When the femoral attachments are avulsed, it may be possible to place a suture in the end of the ligament anchorage is obtained by passing the suture through a hole drilled in the condyle at the original site of attachment.

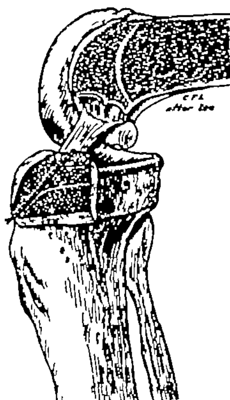


Fig. 207—Reduction of avulsion fracture of attachment of anterior cruciate ligament. (Redrawn from Lee, Harold G J Bone & Joint Surg 19: 460 1937)

Open Reduction of Avulsion Fractures of the Tibial Attachment of the Anterior Cruciate Ligament.—Technic (Lee)—An anteromedial incision is made over the knee and the quadriceps tendon patella and patellar tendon are displaced laterally completely exposing the joint. The semilunar cartilages, if damaged, are removed in their entirety Two holes are drilled from the anterior surface of the tibia to the fracture cavity beginning medial to the attachment of the patellar tendon and three-fourths inch below the margin of the tibia, and converging slightly at the lower end. The drills should emerge at the edges, or immediately outside the edges of the cavity in order that the fragment may be fitted snugly into its normal position. If the fragment is large, a hole may also be drilled through the fragment, although caution should be exercised to prevent splitting of the bone A double suture is passed upward

through one hole in the tibia, thence through the hole in the fragment, or, if the fragment is small, the suture is passed through the anterior cruciate ligament at its attachment to the bone Finally the suture is brought distally through the second drill hole in the tibia and the two ends are drawn tight and tied. If the cruciate ligament is too lax following this procedure, the cavity is enlarged anteriorly and the fragment moved forward

After Treatment.—The knee is placed at 15) degrees' flexion and immobilized in a plaster shell Immobilization is continued for five or six weeks then followed by routine physical therapy and exercise Extension should not be forced

Posterior Cruciate Ligament—Technic (Abbott, et al)—The posterior aspect of the knee is exposed by a midline curvilinear or bayonet incision in the popliteal space The posterior cutaneous nerve is identified and traced to the posterior tibial nerve This structure along with the popliteal artery and vein, are retracted to one side The lateral head of the gastrocnemius is divided transversely above the femoral condyle and retracted medially with the vessels and nerves, thereby exposing the posterior capsule of the joint The posterior segment of the posterior cruciate ligament along with the fragment of bone is located through the defect in the capsule With the knee in slight flexion the bony attachment is accurately fitted into the defect on the posterior rim of the tibia and fixed by a screw or suture

After Treatment.—The extremity is immobilized in a long leg cast with the knee at 160 degrees. Quadriceps setup exercises are begun on the second day Active motion of the knee may be instituted at the third postoperative week, with protected weight bearing at the end of the fifth week.

Repair of Chronic Rupture of the Anterior Cruciate Ligament

In the first edition of this book, the criticism was offered that the Hey Groves procedure was formidable and extensive that the procedure should be used with reserve unless disability was extreme That tenet still holds good We have employed simpler operations (Campbell technic) which followed essentially the same mechanical principles, yet seemed less traumatic. Following a rather devious route however we have returned to the original of all cruciate ligament operations, the Hey Groves technic This procedure was originally described in 1917 in 1920 Hey Groves modified the technic according to a suggestion by Alwyn Smith. The combined operation is described below

Combined Repair of the Anterior Cruciate and Internal Lateral Ligaments (Hey Groves)—A long J or reversed J incision is made along the lateral aspect of the thigh and across the anterior aspect of the knee the most distal portion of the incision being just below the tubercle of the tibia. The tibial tubercle is resected and after incision of the capsule and synovial membrane on each side the patella and capsule are turned proximally (Preferably this procedure should be carried out through an anteromedial utility incision [p 140] combined with a second lateral incision along the thigh function of the quadriceps muscle returns earlier than is possible following the use of the Hey Groves incision) The knee is now flexed and the joint explored A strip of fascia lata 8 inches long and 1½ inches wide is next dissected downward to the lateral incision its attachment at the head of the fibula being retained A ⅜ inch hole is drilled through the external condyle of the femur the opening being

placed as far back as possible on the outer aspect of the intercondylar notch. Another hole is drilled in the tibia, so placed that the inner orifice lies just in front of the tibial spine, and the external orifice presents over the anteromedial or most prominent part of the medial condyle of the tibia. Thus, the new ligament is as oblique as possible in a sagittal plane. A strand of gauze is passed through each hole to remove bone dust or debris The edges of the orifice on the outer aspect of the femur and of that on the articular surface of the tibia are beveled so as to form a smooth funnel-shaped opening Using a piece of gauze as a pilot, the strip of fascia lata is drawn through the hole in the femur, thence through the hole in the tibia, and pulled taut in flexion. The residual three inches of the fascia are passed up along the medial aspect of the joint and fixed to the internal condyle of the femur In general the fascial strip is in line with the anterior border of the internal lateral ligament. Fixation may be secured by sutures or stainless steel staples.

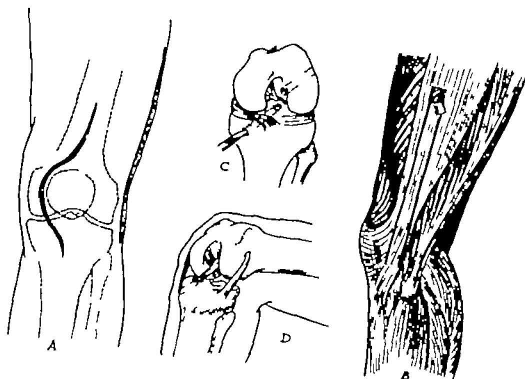


Fig 206.—Hey Groves' technic of combined repair of anterior cruciate and internal lateral ligaments. *A* Operative field may be exposed by anteromedial incision for knee joint and longitudinal lateral incision for fascia, or entire field may be exposed by one long J or reversed J incision. *B* Pedunculated strip of fascia obtained from thigh, attachment at distal end being preserved. *C* Tunnels reamed through lateral condyle of femur and medial condyle of tibia for passage of new ligament. *D* New ligament drawn through tunnels in tibia and femur end of fascia attached to internal condyle of femur to reinforce internal lateral ligament.

After Treatment.—The extremity is immobilized in a long leg cast with the joint at 160 degrees, the cast being substantially windowed to allow for swelling. Suspension in an elevated position will reduce postoperative reaction Quadriceps setups are begun five or six days after the operation. At three weeks the cast is removed, the extremity suspended in a mobilization splint (p 73) and graduated exercises instituted Weight bearing in a locked brace is permissible when the quadriceps is well developed and the joint is extended. Unprotected weight bearing is not resumed for another three months.

Repair of Chronic Rupture of the Posterior Cruciate Ligament

Technic (Gallie and Le Mesurier).—Through an incision on the inner side of the midline posteriorly, extending from the middle of the thigh to the upper portion of the calf the semitendinosus tendon is detached from the muscle as high as possible in the thigh and stripped downward to its insertion. A split patellar skin incision is made (p 143) and its medial edge retracted exposing the insertion of the semitendinosus tendon. The end of this structure is drawn under the sartorius muscle to the front of the leg. The posterior medial incision is then carried down through the deep tissues, the vessels and nerves being retracted laterally, bringing into view the space between the heads of the gastrocnemius muscle this space is widened to expose the posterior capsule of the knee. A hole one fourth inch in diameter is drilled from the posterior aspect of the tibia just below the articular surface to a point close to the insertion of the semitendinosus tendon. By means of a bodkin, the tendon is drawn through the drill hole into the popliteal space (Fig 209)

The patient is placed in the supine position and the patella and patellar tendon are split longitudinally, exposing the interior of the joint. With the knee flexed the bodkin, with the tendon attached, is pushed from behind forward through the posterior capsule at a point just above the hole in the tibia posteriorly and in the normal line of the posterior cruciate ligament. The bodkin is then pushed forward within the synovial sheath of the posterior cruciate ligament, its point emerging at the most anterior attachment of the ligament to the internal condyle of the femur. A third small incision exposes the subcutaneous surface of the internal condyle of the femur, and a one-fourth inch hole is drilled through this structure to appear at the normal insertion of the posterior cruciate ligament. The tendon is then drawn through the internal condyle tightened with the knee in extension and sutured to the internal lateral ligament.

After Treatment.—See above.

Repair of Chronic Rupture of the Anterior and Posterior Cruciate Ligaments

Cubbins and his associates have devised a technic whereby repair of both the anterior and posterior cruciate ligaments may be accomplished at one operation

Technic (Cubbins et al.).—An incision thirteen inches in length is begun ten inches above the knee joint on the lateral aspect of the thigh and carried distally to a point just posterior to and below the head of the fibula. Two strips of fascia lata, each one inch in width, are dissected downward, one to a base at the level of the lateral femoral condyle the other remaining attached to the lateral condyle of the tibia. These strips are utilized to reconstruct the anterior and posterior cruciate ligaments, respectively

The knee joint is exposed by an anteromedial incision (p 140). The synovial membrane and periosteum of the medial condyle of the femur are incised for a distance of two and one-half inches and elevated three-fourths inch. A similar incision is made longitudinally over the anterior medial surface of the internal condyle of the tibia, and the periosteum is again dissected up three fourths inch. With a drill 13/32 inch in diameter three holes

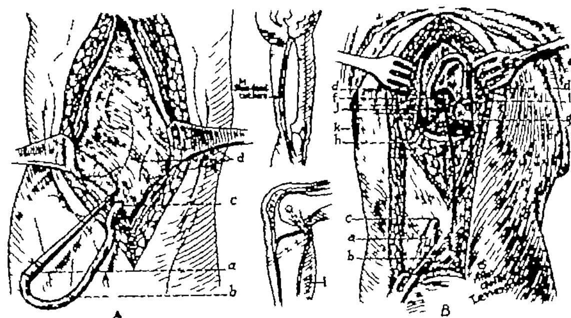


Fig. 209.—Repair of posterior cruciate ligament (Gallie) *A* Steps of procedure through posterior incision. Semitendinosus tendon has been detached from muscle, freed to its insertion on tibia, and passed from before backward through a hole drilled in condyle of tibia. *a*, Sharp pointed bodkin *b* semitendinosus tendon, *c* drill hole through condyle of tibia *d*, dotted lines outline the bones and posterior cruciate ligament. *B* Steps of procedure through anterior incision. Bodkin has been passed through posterior capsule and along posterior cruciate ligament, beneath synovial membrane, to point of attachment of posterior cruciate ligament to femur New ligament anchored by means of a hole drilled through internal condyle of femur *a* Semitendinosus tendon *b* insertion of sartorius *c* hole through condyle, *d*, split patella retracted *f* posterior cruciate ligament *g* anterior cruciate ligament *h* hole in synovial membrane *i* end of semitendinosus tendon *j* wire loop through hole in internal condyle of femur *d*, small medial incision. Insert shows sagittal section through joint and operation completed. (Redrawn from Gallie and LeMesurier Ann. Surg 85: 592 1927)

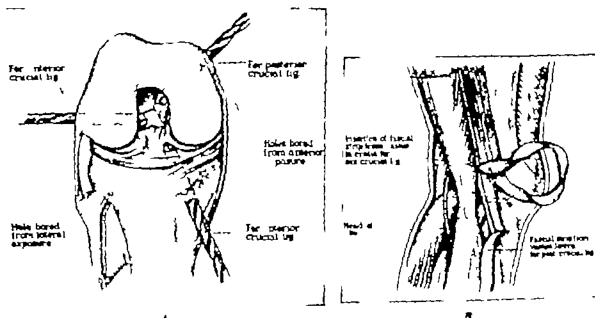


Fig. 210.—Combined repair of anterior and posterior cruciate ligaments. (Cubbins et al.) *A*, Holes made for insertion of new ligaments. *B* Dissection of strips of fascia for new anterior and posterior cruciate ligaments. (From Cubbins, W R., Callahan, J J and Scuderi, C. S. Surg., Gynec. & Obst. 64 221, 1937)

are made in the condyles for insertion of the new ligaments. The first hole is drilled through the medial condyle of the femur obliquely downward and anteriorly from without inward (Fig. 210A) The other two holes are to serve for the passage of the anterior cruciate ligament For the first of these the drill

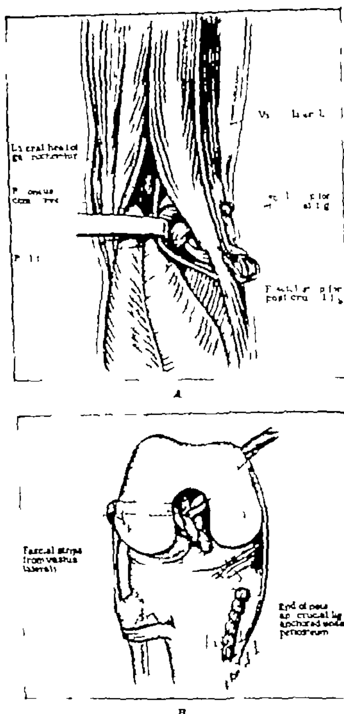


Fig. 211.—Same as Fig. 210 A, New posterior cruciate ligament being drawn through fascia over head of fibula and beneath gastrocnemius peroneal nerve, and popliteus tendon. B, Repair of ligaments completed. (From Cubbins, et al. Surg. Gynec. Obst. 64: 221, 222, 1937)

point is placed in the osteoperiosteal bed which has been prepared on the internal condyle of the tibia, and passed obliquely upward and forward to emerge just anterior to the spine of the tibia the remaining hole is drilled horizontally through the posterior portion of the lateral condyle of the femur The new

ments are slightly twisted and the strip for the anterior cruciate ligament rawn through the hole in the external condyle of the femur into the knee it. The new posterior cruciate ligament is then carried through the fascia ering the head of the fibula and inserted beneath the lateral head of the rocnemius muscle peroneal nerve and the popliteus tendon thence through posterior capsule into the knee joint, and on through the medial condyle he femur *The new anterior cruciate ligament is next drawn through the* nel in the internal condyle of the tibia. Both ligaments are pulled taut i the knee flexed 155 to 145 degrees, and sutured in their respective osteo-osteal beds. In closure of the deep structures, which is accomplished i continuous catgut sutures, one from below and one from above, a small e is left in the midportion of the incision to permit the escape of hemorrhage. skin is closed loosely with clips.

After Treatment.—(See above.)

HYPERTROPHY OF VILLI AND INFRAPATELLAR FAT PAD

The symptoms of hypertrophic villi and enlargement of the infrapatellar *pad are similar to those produced by derangement of the cartilage, al* igh much less severe and much more rare. In fact, symptoms so seldom e from villi or fat pads that the indication for operation usually is question : Not infrequently however a diagnosis of these lesions is made to condone operation wherein little or no abnormality is found

We have no quarrel with those who would excise a few fibrotic tips or folds he infrapatellar fat pad in conjunction with procedures on the knee joint h rare exception, there is little reason to remove the entire fat pad.

LOOSE BODIES IN JOINTS

There are four different types of loose bodies for which operative measures indicated (1) osteochondritis dissecans, (2) *osteochondromatosis or* ovial osteochondromata (3) detached osteophytes and (4) fragments from tures of the articular surfaces or segments of the *articular cartilage or* llunar cartilages.

A perusal of the statistics of the Army Air Forces Orthopedic Service vides some interesting information as to the incidence and source of loose ies. The number of arthrotomies carried out for loose bodies was second to those for lesions of the menisci. In slightly more than one-half of 186 s, the loose bodies were incident to osteochondritis dissecans in one-third he cases, the origins of the loose bodies could not be determined. Fractures he articular surface represented approximately 11 per cent, and osteochon matosis 2 *per cent. In 13 per cent of the cases*, loose bodies were located he posterolateral or posteromedial compartments of the knee.

Even though the loose bodies apparently are limited to the posterior com tment, a generous anteromedial incision should be made to permit thorough pection of the anterior compartment. The loose bodies in the posterior com tment are readily accessible through a Henderson incision (p 144)

More than one loose body is present in approximately one-third of the cases. roentgenograms may give an erroneous impression in this regard they do disclose the presence of cartilaginous loose bodies. Without exception, roent

genograms should always be made prior to closure of the wound. In one Army Air Force case, the preoperative films revealed the presence of three large loose bodies. At operation, three were found and removed. Roentgenograms were



Fig. 212.—Large, loose body in lateral portion of suprapatellar pouch smaller body in posterolateral compartment. Small fragment of bone opposite posterior surface of external condyle of femur is a sesamoid bone in lateral head of gastrocnemius muscle, not a loose body

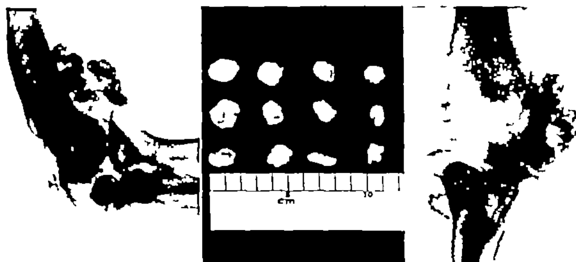


Fig. 213.—Multiple loose bodies in elbow Eleven osteocartilaginous bodies can be counted in roentgenograms, twelve loose bodies were removed. Roentgenograms should always be made prior to closure of joint.

not made in the operating room Two weeks postoperatively one of the three loose bodies visualized in the original roentgenogram was still present in the intercondylar notch Obviously there were four loose bodies, one without a bony center

Osteochondritis Dissecans

This condition is observed chiefly in the knee joint. Less frequently loose bodies are found in the elbow ankle shoulder and hip Only operative treatment as applied to the knee will be described the surgical procedures followed in other joints being essentially similar

Symptoms from loose bodies in the knee joint are, as a rule, less severe than those induced by derangement of the semilunar cartilages. The patient complains of a dull, aching pain in the joint and often states that he can palpate a loose body Palpation of such a body or bodies by the surgeon and roentgenographic studies will substantiate the patient's statement. Surgery may be undertaken while the loose body is still retained in a cavity on the articular surface before extrusion into the joint takes place this condition is, *of course, confirmed only by a roentgenogram Although advised by* some authors, watchful waiting until the body is extruded into the joint is neither necessary nor desirable.

Unless loose bodies are retained in situ locking is frequently the predominant symptom and in contrast to the locking incident to lesions of the semilunar cartilage is often only momentary being followed by spontaneous relief with a snap of the loose fragment as it passes from between the joint surfaces. A pedunculated loose fragment may also pass in and out spontaneously causing frequent episodes of momentary locking Usually, only a slight reaction is associated. The patient rapidly becomes adept at disengaging the loose body *with a little maneuvering*

If the symptoms have been of short duration, a single loose body may be expelled into the joint whereas, if the affection is of long standing three or more may be found. The number and location of those containing bone may be determined by the roentgenogram cartilaginous bodies, however may not be visible Rarely the body may be partially detached one portion acting as a hinge, and move back and forth into and out of the cavity causing irritation and reaction. Or a loose body from a distant portion of the joint may adhere to the joint surface and become attached secondarily by a pedicle

As a rule, these lesions are confined to the lateral aspect of the internal condyle adjacent to the intercondylar notch, although they may be found on the posterior aspect of the patella in the lower medial quadrant and, in a few cases, on the external condyle of the femur Whatever the location, the operative principles are the same

Technic.—The joint is exposed by a three-inch anteromedial incision. In a large number of cases this incision will give access to the entire disease process, although occasionally a body may have become attached to some portion of the joint, such as the posterior compartment necessitating a separate incision If irritation is pronounced, a straw-colored serous fluid will escape when the synovium is incised. The joint is thoroughly searched for all loose bodies and any other mechanical derangement, especially of the semilunar cartilages. The knee is then slowly flexed and extended, bringing into view a cavity usually one-half to one inch in diameter on the intercondylar portion of the medial condyle. All detached and loosely attached particles are curetted *from the cavity and the* overhanging edges of cartilage trimmed away *When the loose body is attached* by a hinge, this is excised intact.

Occasionally, the hyaline cartilage remains attached over the loose body and the only evidence of its presence on inspection is a small elevated area on the articular surface of the internal condyle of the femur, slightly lateral to the main weight bearing surface i e, near the attachment of the posterior cruciate ligament to the medial condyle The edges of this elevated area are usually *slightly depressed or indented* *The cartilage over the nonviable area of* bone usually presents a yellowish discoloration in contrast to the white, glistening, normal articular cartilage and may show more advanced signs of degeneration. In relatively recent osteochondritis dissecans, and particularly in young individuals, the cartilage may present an entirely normal appearance. In this event, a heavy straight skin needle may be used as a probe Whereas normal cartilage is rubbery and resistant in consistency, the cartilage over the *area of necrosis is less resistant* and doughy The nonviable body having been located an incision is made in the cartilage around this area and the loose body is removed with its cartilaginous covering or if not completely detached, the pathologic bone is removed with a curette to normal bleeding bone.

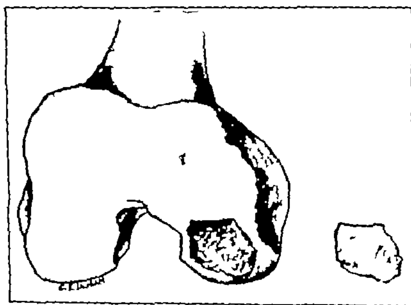


Fig 214 —Osteochondritis dissecans with defect in condyle of femur Insert shows loose body

One should then review the roentgenograms made prior to operation, to see that all particles are removed. The joint is now flexed, extended, and massaged in every direction to extrude any remaining bodies. The suprapatellar pouch in particular should be inspected. Should there be any question of a persistent body a careful digital examination should be made a fresh sterile glove being worn for the purpose a small loose cartilaginous body which is not visible in the roentgenogram may be found. Following this procedure roentgenograms are made in both planes to insure removal of all loose bodies shown on the preoperative film Finally the joint is thoroughly lavaged with sterile saline solution to float out any particles of bone dust or small fragments of cartilage

After Treatment.—Postoperative care and rehabilitation of the joint are carried out along essentially the same lines as those for other types of internal derangement (p 249) with the following exceptions hemorrhage from the raw

surface of the condyle of the femur is frequently sufficient to warrant aspiration The mobilization stage of rehabilitation should be delayed until fourteen days following operation, or even perhaps three weeks, depending upon the reaction. The weight-bearing period is commensurately delayed, as the raw surface usually involves a portion of the weight bearing surface of the femoral condyle.

Defects which involve a major segment of the weight bearing surface of the femoral condyle will eventually produce some degree of disability from degenerative arthritis. The minor lesions, particularly those primarily located in the periphery of the weight-bearing surface and involving the intercondylar notch produce little or no disability Persistent disability may also arise from retained loose bodies or from secondary changes already present incident to an irritating lesion of long duration

Osteochondromatosis

This is a rare pathologic process characterized by the formation of synovial osteochondromata. The symptoms consist principally of pain and limitation of motion. Any joint may be involved though primarily the large joints are affected, the majority of cases having been reported in the knee and, less commonly the hip and shoulder

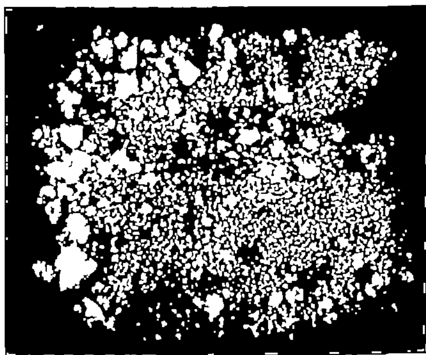


Fig. 215.—Loose bodies removed from knee joint. Diagnosis: osteochondromatosis.

Knee

The bodies are formed from the synovial membrane In many cases they are present in large numbers often a hundred or more are found, and even thousands have been reported. The pathologic process varies considerably There may be multiple loose bodies in the joint while the synovial membrane remains apparently normal, or there may be extensive changes of the entire



Fig. 216.—Extensive osteochondromatosis of knee. Removal of loose bodies required complete synovectomy of posterior compartment and partial synovectomy of anterior compartment.



Fig. 217.—Osteochondromatosis of hip before and after surgery

synovium or a portion thereof Small cartilaginous titlike projections of the villi may be observed in the process of forming multiple loose bodies this type is usually associated with a thickened synovium Because of the constant irritation, the pathologic changes may resemble those of traumatic arthritis or localized osteoarthritis.

Treatment consists of removal of the loose bodies and a complete or partial synovectomy (Ch. XIII) The extent of the synovectomy is dependent upon the extent of the pathologic process. The following procedure was utilized in one case, as illustrated in Fig 216

With the patient in a prone position a curved posterior longitudinal incision was made across the knee joint the nerves and vessels being retracted to expose the posterior aspect of the joint The capsule was distorted by numerous groups of irregularly sized tumors, which in turn were composed of innumerable small loose bodies, matted together These masses occupied practically the entire posterior compartment of the joint, even protruding into the posterior portion of the intercondylar notch of the femur A large circular area over the lateral surface of the medial condyle was eroded and occupied by one of these tumor masses. All of the masses were friable, and broke easily when dissected away In addition discrete small cartilaginous and osteocartilaginous bodies were found growing from the synovium Thorough eradication of the small tumor masses necessitated an almost complete posterior synovectomy The attachment of the posterior cruciate ligament to the tibia had been almost wholly destroyed by pressure necrosis from a tumor growth The remainder of the posterior portion of the cruciate ligament was destroyed in removal of the intimately attached cartilaginous bodies. The posterior incision was then loosely closed, the patient placed in a supine position and the anterior compartment of the knee exposed by an anteromedial incision The same process was found in the anterior portion of the joint, the synovium and the semilunar cartilages being widely involved. Eradication of the tumor masses necessitated a rather extensive synovectomy and meniscectomy Postoperative roentgenograms were made to verify complete excision of the osteocartilaginous bodies. The patient regained normal function of the knee and no evidence of recurrence of the growths was present two years postoperatively

After Treatment.—(See Synovectomy Chapter XIII.)

In a few cases the condition recurs repeatedly although the synovial membrane may be apparently normal on inspection. Generally however relief is permanent

Hip

In the hip removal of all loose bodies from the capsule of the joint is considerably more difficult than in the knee

Technic.—Through an anterior iliofemoral incision (p 146) the capsule is incised longitudinally throughout its length Usually the synovial fluid will be materially increased Irrigation of the cavity with saline solution will facilitate removal of the loose osteocartilaginous bodies. With a fresh glove, a thorough digital examination is made. The findings on inspection should be confirmed by a roentgenogram A complete synovectomy as may be performed in the knee joint is of course not feasible.

Detached Osteophytes

Osteoarthritis may give rise to loose bodies from osteophytes detached from the margin of the joint. After remaining loose in the joint, they undergo changes similar to those of other loose bodies and impinge upon the joint surfaces. Symptoms of impingement, palpable bodies, and roentgenographic demonstration are indications for operation.

Loose Bodies Following Fracture

Loose bodies associated with fractures involving the articular surface usually are removed at the time of open reduction of the fractures. If discovered subsequently, the treatment is similar to that described for other loose bodies.

PELLEGRINI-STIEDA'S DISEASE

This term is a misnomer; "ligamentum ossificans" might be more applicable. The characteristic lesion consists of a semilunar shaped bony mass in the anterior fibers of the internal lateral ligaments near the femoral condyle. The more proliferative lesions may present relatively large irregular areas of ossification. We have observed the same process in the external lateral ligament.

The process of development is similar to that of lesions on the medial aspect of an elbow in baseball pitchers, and of myositis ossificans, i.e., injury, hematoma, calcification and ossification.

The therapy of most of these heterotopic lesions follows a relatively common pattern. If the initial injury receives proper treatment, chiefly immobilization, the lesion will not develop or will be of slight degree. The ligamentous injuries of the knee are regarded as simple sprains and the patient ordinarily does not seek the aid or advice of a doctor. When first observed, the process of ossification is usually fairly well advanced; the patient complains of pain over the region of the adductor tubercle and limitation of motion of the knee, and an area of tenderness and tumefaction may be elicited. At this stage of immaturity, overzealous attempts at treatment, particularly mobilization and massage, merely stimulate and prolong the evolution of the process. Surgery is definitely contraindicated during the formative period. Kulowski reports one case wherein removal of the bony mass was followed by a recurrence of bone formation which was more extensive than the original mass. Conservative measures must be carried out until the bony mass manifests a regular, rounded, circumscribed and relatively dense lesion. Premature ossification exhibits a fluffy, less dense irregular pattern.

The evolutionary process of the heterotopic bone formation from injury to complete maturity requires from nine to twelve months. During this time one must observe a policy of "skillful neglect." By the end of this period many of these areas will have been partially or occasionally wholly absorbed, and will no longer cause symptoms or interfere with function of the knee. On the other hand, the mass may be sufficiently large and the symptoms sufficiently severe to warrant excision.

Technic.—A longitudinal incision three inches in length is made over the internal condyle of the femur on the medial aspect of the knee. Exposure is not difficult, in that the mass is relatively subcutaneous at the adductor tubercle.

Discrete masses are removed by sharp dissection. The more extensive lesions may intimately involve the proximal end of the ligament, the attachment of the adductor magnus muscle and adjacent portions of the vastus medialis muscle. Or the mass may be an intimate part of the femur and require removal with an osteotome in much the same manner as an osteochondroma.

After Treatment.—The extremity should be immobilized for a period of ten days. Weight-bearing is then instituted, the joint being supported by a cage knee brace. No motion is allowed for an additional month, and free use of the knee is not encouraged until the lapse of three months. The after treatment of the less extensive lesions may be less cautious.

Ossification may partially recur in the area of resection, though recurrence will be minimized if surgery is reserved for those cases which present definitely mature lesions.



Fig. 218.—Ossification of internal lateral ligament secondary to injury. Typical so-called Pellegrini-Stieda's disease, represented by half-moon ossification, region of adductor tubercle of femur

LESIONS OF THE PATELLA

During the latter part of World War II, lesions of the patella were recognized as a common source of internal derangements of the knee, capable of producing rather considerable disability without other pathologic processes. Earlier their existence frequently was not suspected until the joint was visualized at arthrotomy for other internal derangements. Gradually this source of disability assumed more and more importance and was recognized more often. Luck classifies these lesions as follows

1 Chondromalacia of the patella of idiopathic origin, or from acute trauma (contusion or twist) or a valgus quadriceps mechanism

2 Osteochondritis dissecans
3 Recurrent dislocation or subluxation of the patella
4 Bipartate patella
5 Hypertrophic arthritis
6 Fractures of the patella (malunited ununited, marginal, or tangential)

The predominant symptoms in this group of lesions consists of a catching or "giving away" on flexion and extension of the knee, such as going up and down steps, pain on motion, and a sensation of grating and grinding Crepitus between the patella and the femur particularly on full flexion, is the most predominant finding Some of the patellar lesions may be associated with mild effusion in the joint following excessive activity or rotary strains of the knee

Roentgenograms are of little value in determining the extent of damage to the articular cartilage. An osteochondritis dissecans of the patella is best visualized in a slightly overexposed lateral view The bipartate patella, or marginal fractures may be visualized in the anteroposterior view, and in the Waters position

For details as to treatment, we refer the reader to the following sections chondromalacia of the patella (Chapter XIII), recurrent dislocation of the patella (p 310) hypertrophic arthritis of the knee (Chapter XIII) osteochondritis dissecans (p 272) ununited fractures of the patella (p 640) and tangential fractures of the patella (p 411)

A word or so about the remainder Osteochondritis dissecans of the patella is usually associated with a chondromalacia which is considerably more extensive than the peripheral margins of the avascular portions of the bone. In general treatment is carried out as described above for osteochondritis dissecans of the femur Residual disability is more or less directly proportionate to the size of the chondromalacic changes. The latter are rarely so extensive as to warrant patellectomy Almost without exception the patella should be given the benefit of the doubt if necessary patellectomy may be carried out later

The treatment of bipartate patella and marginal fractures of the patella is essentially the same if the roentgenograms reveal sufficient incongruity and irregularity of the articular surface of the patella, the small marginal fragment is excised. These two lesions assume some medicolegal importance, in that the former is of congenital origin and may be confused with the latter

TRAUMATIC ARTHRITIS OF THE SPINE

Uncomplicated acute traumatic spondylitis usually responds well to conservative treatment There is, however one clinical entity Kümmell's disease which is supposedly a sequel to spinal injury, wherein operative measures may be necessary The symptoms and signs are not manifested until weeks or months after injury The kyphos, which develops gradually, may simulate that of tuberculosis of the spine.

The treatment consists of immobilization of the spine in slight hyperextension until the symptoms have disappeared This may be accomplished by plaster casts or braces If these measures do not prove successful, fusion of the affected region may be indicated

Coccygodynia Painful Coccyx

Coccygodynia should be differentiated into two types, traumatic and functional. Surgery is positively contraindicated in the latter, as many of these cases improve or are exacerbated by any form of therapy or no therapy The functional type of coccygodynia is usually observed in a highly nervous woman the onset is insidious and there is no history of trauma. It is a local manifestation of a general nervous instability

There are two types of surgical sacrococcygeal joints (1) the rigid coccyx with pain on pressure in a sitting position (2) traumatic arthritis in a movable sacrococcygeal joint with prominence of the lower end of the sacrum and the coccyx to the degree that it is subjected to constant trauma. Pain should be localized to the joint and not invade adjacent soft tissue structures such as the buttocks or thighs. Symptoms referable to the low back region definitely contraindicate surgery Even in the presence of severe angulation surgical intervention is not warranted in acute injuries of the sacrococcygeal articulation Conservative measures should be carried out for at least six months.

To distinguish patients who are not likely to be benefited by surgery Steindler advocates infiltration of the coccygeal region with novocaine if relief is obtained temporarily excision of the coccyx will probably alleviate the symptoms.

Despite careful selection of cases, a few patients may have persistent pain. The operation consists of excision of the coccyx.

Technic.—The skin and subcutaneous tissue are incised in the midline over the lower portion of the sacrum and coccyx. The sacrococcygeal articulation is separated, the proximal end of the coccyx is grasped with an Ochsner forceps, and the bone is removed from above downward dissection being made close to the bone. As an added precaution, the left hand may be placed beneath the drapes and the gloved index finger inserted into the rectum to serve as a guide during the dissection of the deep surface of the coccyx. An assistant closes the wound, or the surgeon may redress, if he is to continue the operation

After Treatment.—Care should be exercised to prevent infection by feces and urine for this purpose a commode rather than a bedpan should be employed. Collodion dressings will aid in preventing contamination of the wound. The patient should be instructed to use a horseshoe-shaped pillow, or a rubber cushion for two or three months to prevent contusion or pressure of the coccygeal area

TRAUMATIC ARTHRITIS OF THE SHOULDER

(Baseball Pitcher s Shoulder)

Traumatic injuries about the shoulder are frequently of occupational origin i.e. the result of repeated severe strains on the joint structures. The disability may arise from a pathologic process in a single structure or tissue, or as is more often the case, a combination of injuries to the tendons, bursae, synovium, and cartilaginous surfaces of the joint perhaps eventuating in a true osteoarthritis with loose bodies

Bennett in discussing injuries of this nature in baseball players, points out a variety of entities. Frequently the lesion is similar to the supraspinatus

syndrome (Ch XX) In baseball pitchers, particularly there are two groups of lesions which differ from those routinely observed The anterior group are caused by trauma to the soft tissue structures as the head of the humerus presses against the coracoid process on the finish of the follow through of the pitch These usually respond to conservative treatment Lesions of the posterior compartment are due to the severe strain and pull on the posterior capsule and synovial membrane, together with the direct repeated trauma to the posterior inferior border of the glenoid, the latter produces an arthritis in the form of an ordinary osteoarthritic spur The irritation of the capsule and synovium may lead to an irritation of the circumflex nerve with radiating pains referred to the deltoid region The extent of the pathologic process in the bone and joint is demonstrable by two view roentgenograms of the shoulder Surgical treatment consists of posterior exposure of the shoulder joint and removal of the exostosis.

Technic (Bennett) —The incision is made along the spine of the scapula the deltoid muscle being detached and retracted laterally (p 159) Dissection is then continued between the teres minor and infraspinatus muscles, thus avoiding damage to the suprascapular nerve which supplies the infraspinatus from above and the nerve supply to the teres minor from the circumflex nerve below Retraction of the two muscles at the level of the shoulder joint reveals the posterior capsule and posterior inferior aspect of the glenoid (The variation of Rowe and Yee wherein the infraspinatus tendon is incised transversely may facilitate this exposure) The exostosis is then excised

After Treatment.—No special measures are required in the after treatment of this lesion other than a routine care of the wound and the exercises and physical therapy necessary to rehabilitation of the joint

TRAUMATIC ARTHRITIS OF THE ELBOW

(Baseball Pitcher s Elbow)

The lesions commonly associated with the elbow in veteran pitchers are characteristic traumatic arthritis with thickening of the synovial membrane fibrillation of cartilage and mild hypertrophic changes about the junction of the cartilage and bone Loose bodies usually are present in the joint Small calcified bodies possibly chip fractures, or metaplastic bone as observed in Pellegrini-Stieda s disease are also encountered in the common origin of the flexor muscles. Kirby has observed a chip fracture on the posterior inner surface of the radius in two baseball pitchers Both obtained a satisfactory result following removal of the loose fragment

Treatment consists of removal of calcifications from the region of the internal condyle of the humerus and if present loose bodies from the elbow joint. In traumatic arthritis of long standing the osteophytes are trimmed from the olecranon and olecranon fossa when the elbow reaches this status of degeneration the patient s pitching days are numbered.

TRAUMATIC ARTHRITIS OF THE WRIST

Traumatic arthritis or sprain of the wrist may be followed by a slowly progressive degenerative lesion of the semilunar bone known as Kienböck's disease, or a similar lesion of the scaphoid bone known as Preiser s disease



Fig. 219.—Traumatic arthritis of elbow (baseball pitcher' elbow). Loose body in anterior compartment, calcification in attachment of flexor muscles to internal condyle and hypertrophic changes of olecranon and head of radius.

The condition is caused, presumably by interference with the vasomotor equilibrium which may be in the form of hyperemia, with decalcification of the bone, or the opposite, partial or complete obstruction of the circulation, and an apparent increase in density of the bone as compared with the other carpal bones In the latter event the lesion is supposedly induced by partial dislocation and spontaneous replacement of the bone The rarefaction is similar to that of Kümmell's disease and the absorption that may be observed in central fractures of the neck of the femur In some cases, eburnation of the bone suggests a low grade inflammatory process, in others, the bone is apparently an aseptic sequestrum from inadequate blood supply The treatment consists of prolonged immobilization of the wrist and if this proves ineffectual, excision of the bone

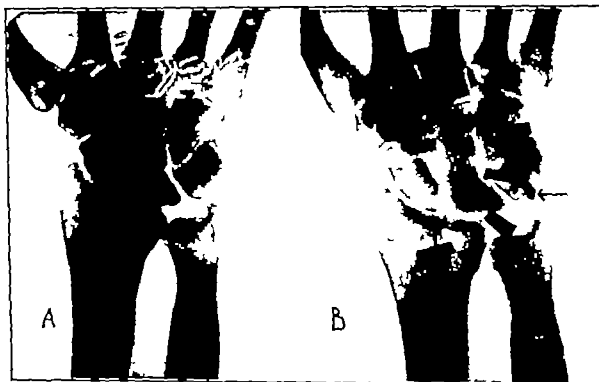


Fig. 220.—Kienböck's disease. *A* Aseptic necrosis of semilunar bone secondary to fracture. *B* Operating room roentgenogram. To identify semilunar bone prior to removal, skin clip as indicated attached to triangular bone.

References

Abbott, L. C., Saunders, J B deC. M., Bost, F C., and Anderson, C E.: Injuries to the Ligaments of the Knee Joint, J Bone & Joint Surg 26 503 1944.

Albee, Fred H.: Sixty Four Joint Mice in the Shoulder, J Bone & Joint Surg 9 601, 1927

Apley A. G The Diagnosis of Meniscus Injuries. Some New Clinical Methods, J Bone & Joint Surg. 29 78 1947

Bassocchi, Giovanni: The Regenerative Power of the Semilunar Cartilages in Relation to Therapy Ann. ital. di chir 14 1237 1935.

Bennett, G E.: The Use of Fascia for the Reenforcement of Relaxed Joints, Arch. Surg 13 655 1926.

Bennett, G E. Shoulder and Elbow Lesions of Professional Baseball Pitcher J A. M. A. 117 510, 1941.

Bennett, G E., and Shaw, M. B. Cysts of the Semilunar Cartilages, Arch. Surg. 33 92, 1936.

Boppe, Marcel, et al.: The Operative Treatment of Fractured or Displaced Semilunar Cartilage, J Bone & Joint Surg 14: 229 1932.

Bosworth, D M.: An Operation for Meniscectomy of the Knee J Bone & Joint Surg 19 1113, 1937

Boyd, H. B. and Hawkins, B L. Patellectomy A Simplified Technique, Surg., Gynec. & Obst. 86 357, 1948
Brackett, E. G., and Hall, C L. Osteochondritis Dissecans, Am. J Orthop. Surg. 15 79 1917
Brantigan, O C., and Voshell A F Ligaments of the Knee Joint J Bone & Joint Surg. 28 66 1946.
Brantigan O C., and Voshell, A. F The Mechanics of the Ligaments and Menisci of the Knee Joint, J Bone & Joint Surg 23 44, 1941.
Brantigan, O C., and Voshell, A. F The Tibial Collateral Ligament Its Function Its Bursae, and Its Relation to the Medial Meniscus J Bone & Joint Surg. 25 1*1, 1943
Bristow W R. Internal Derangement of the Knee Joint, J Bone & Joint Surg. 17 60., 1935.
Bristow, W R. Internal Derangement of the Knee Joint, Am. J Surg 43 458 1939
Bristow W R. Anatomical Variation of the Semilunar Cartilage Proc. Roy Soc. Med., Vol. 21 Part I Section of Orthopedics, p. 241 1927 28
— Cysts of the Semilunar Cartilages of the Knee, Robert Jones Birthday Volume, London, 1928 Oxford University Press, p. 209
— Internal Derangement of the Knee-Joint, J Bone & Joint Surg 7 413 1925
— Internal Derangement of the Knee Joint, J Bone & Joint Surg 17 605 1935.
Bruce J., and Walmsley R. Replacement of Semilunar Cartilages of Knee After Operative Excision, Brit. J Surg. 25 17, 1937
Buckley E. J Pelligrini-Stieda Disease U S. Nav M. Bull. 44 947 1945.
Burman, M., and Sinberg, S. E. Condylar Movement in the Study of Internal Derangement of the Temporomandibular Joint, J Bone & Joint Surg. 28 351, 1946.
Campbell, Willis C. An Operation for Repair of the Internal and External Lateral Ligaments of the Knee Joint, Surg Gynec. Obst. 60 214, 1935.
— Differential Diagnosis of Traumatic Arthritis J Lab & Clin. Med. 22. 30 1936.
— Internal Derangement of the Knee Surg Gynec. Obst. 52 563, 1931
— Injuries and Surgical Diseases of Joints. Dean Lewis Practice of Surgery Vol. II Chap. V Hagerstown 1927 W F Prior Co., Inc.
— Repair of the Ligaments of the Knee, Surg Gynec. Obst. 62 964 1936.
— Reconstruction of the Ligaments of the Knee Am. J Surg. 43 473, 1939
Campbell, W C., and Mitchell, J L: Loose Bodies in Joints, Indianapolis M. J 32 521, 1929
—: Semilunar Cartilage Cysts, Am. J Surg. 6 330 1929
Carrell, W B Use of Fascia Lata in Knee-Joint Instability J Bone & Joint Surg 19 1018 1937
Cave E. F Rowe C. R., and Yee L. B. K. Selection of Cases for Arthrotomy of the Knee in an Overseas General Hospital A Two-Year Follow Up Study J Bone & Joint Surg 27: 603 1945
Cave, E. F., and Staples, O S Congenital Discoid Meniscus Cause of Internal Derangement of Knee Am. J Surg 54 371 1941.
Charnley J Exposure of Posterior Horn of Medial Meniscus Lancet 2 71 1944.
Cleveland M., Willein, L. J., and Doran, P C.: Surgical Treatment of Internal Derangement of the Knee Joint Among Troops in Training at Fort Jackson, South Carolina, J Bone & Joint Surg. 26 829, 1944.
Colonna, P C. Osteochondromatosis of the Knee Joint, Surg Gynec. Obst. 53 698 1931
Cubbins Wm. R., Conley A. H., Callahan J J., and Scuderi C. S. A New Method of Operating for the Repair of Ruptured Cruciate Ligaments of the Knee Joint, Surg. Gynec. Obst. 54 299 1932.
Cubbins, Wm. R., Callahan J J., and Scuderi, C. S. Cruciate Ligament Injuries, Surg Gynec. Obst. 64 218 1937
Duthie J J R., and MacLeod, J G Rehabilitation After Meniscectomy; Experience at Army Convalescent Depot, Lancet 1 197 1943
Edwards, A. H. Operative Procedure Suggested for the Repair of Collateral Ligaments of the Knee-Joint, Brit. J Surg 8 266, 1921
Fairbank, H. A. T Internal Derangement of Knee in Children and Adolescents, Proc. Roy Soc. Med. 30 427, 1937
Finder J G Calcification of the Tibial Collateral Ligament A Report of Forty Two Cases, J A M A. 102 1373, 1934.
— Discoid External Semilunar Cartilage. A Cause of Internal Derangement of the Knee Joint J Bone & Joint Surg 16 804 1934
Fisher A. G T Internal Derangements of the Knee-Joint ed. 2, London W C. I., 1933 H. K. Lewis & Co.
Freiberg, A H. Osteochondritis Dissecans, J Bone & Joint Surg. 5 3, 1923
— The Removal of the Meniscus From the Knee Joint J Orthop. Surg 3 607 1921.
Gallie, W E., and LeMesurier A. B. The Repair of Injuries to the Posterior Crucial Ligament of the Knee-Joint Ann. Surg. 85 592, 1927
Geschickter C. F., and Copeland, M. M. Tumors of Bone New York, 1931 The American Journal of Cancer

Groves, E. W Hey: Operation for Repair of the Crucial Ligaments, Lancet 2 674 1917
— The Crucial Ligaments of the Knee-Joint Their Function, Rupture, and the Operative Treatment of the Same Brit. J Surg 7 505, 1920.
Haggart, G E.: Synovial Cysts of the Popliteal Space; *Clinical Significance and Treatment* Ann. Surg. 118 438, 1943.
Hauser E. D W Loose Body of the Knee Derived From the Meniscus, J Bone & Joint Surg. 24 307, 1942.
Hedrick, Donald W., and Jones, Horace C.: Pellegrini-Stieda s Disease Clinical and Roentgenologic Considerations, Radiology 23 180 1934
Henderson, Melvin S: Bucket Handle Fractures of the Semilunar Cartilages, J A. M. A. 90 1350, 1928.
— Chronic Osteitis of the Semilunar Bone (Kienböck's Disease), J Bone & Joint Surg 8 504, 1926.
— Injuries to the Semilunar Cartilages of the Knee Joint, Surg Gynec. Obst. 51 720, 1930
Henderson, M. S., and Jones, H. T: Loose Bodies in Joints and Bursae Due to Synovial Osteochondromatosis, J Bone & Joint Surg 5 400 1923
Jones, Hugh T Loose Body Formation in Synovial Osteochondromatosis With Special Reference to the Etiology and Pathology J Bone & Joint Surg 6 407 1924.
Jones, R., and Lovett, R W Orthopedic Surgery, New York, 1924, Wm. Wood & Co., p. 83
Jones, R., and Smith, S. A.: On Rupture of the Crucial Ligament of the Knee, and on Fractures of the Spine of the Tibia, Brit J Surg. 1 70 1913
Key J A. Operative Treatment of Coccygodynia, J Bone & Joint Surg 19 759 1937
Kienböck, Robert: Ueber traumatische Malazie des Mondbeins und ihre Folgezustände Entartungsformen und Kompressions-frakturen, Fortschr a. d. Geb. d. Röntgenstrahlen. 16 77, 1910.
King Don The Function of Semilunar Cartilages, J Bone & Joint Surg 18 1069 1936.
— The Healing of Semilunar Cartilages, J Bone & Joint Surg 18 333, 1936.
Kirby F J Foreign Bodies in the Elbow Joints: 'Baseball Pitchers Elbow,' J A. M. A. 95 404, 1930.
Kleinberg Samuel Cyst of the External Semilunar Cartilage With Report of a Case, J Bone & Joint Surg 9 323 1937
Kleinberg, S. Cysts of External Semilunar Cartilage Report of Three Cases Arch. Surg 37 827 1938
Kulowski, Jacob *Pellegrini-Stieda s Disease Report of One Case Surgically Treated,* J A. M. A. 100 1014, 1933
Kümmell, H.: Ueber die traumatischen Erkrankungen der Wirbelsäule Deutsche med. Wchnschr 21 180 1895
Lee, Harold G: Avulsion Fracture of the Tibial Attachments of the Crucial Ligaments, J Bone & Joint Surg. 19 460, 1937
Lipscomb, P R., and Henderson, M. S.: Internal Derangements of the Knee, J A M. A 135: 827 1947
Luck, J V: Orthopedic Rehabilitation, Air Surgeon s Bull. 2 431, 1945.
McMurray T P: The Diagnosis of Internal Derangements of the Knee The Robert Jones' Birthday Vol. London, 1928.
McMurray, T P The Semilunar Cartilages, Brit. J Surg 29 407, 1942.
McReynolds, I. S.: Cysts of the Semilunar Cartilages, South M. J 32 571, 1939
Mauck, H. Page A New Operative Procedure for Instability of the Knee J Bone & Joint Surg 18 984 1936.
Middleton D. S.: Congenital Disc-Shaped Lateral Meniscus With Snapping Knee Brit. J Surg 24 246, 1936
Milch H Injuries to the Crucial Ligaments Arch. Surg. 30 805 1935
Milch, H. Fascial Reconstruction of the Tibial Collateral Ligament Surgery 10 811 1941,
Murray C R. Treatment of Injuries to the Knee Joint New England J Med 236 263 1947
Nachlas, I. W, and Olpp J L. Para Articular Calcification (Pellegrini Stieda) in Affections of the Knee Surg., Gynec. & Obst. 81 206, 1945.
Odessky I. M. Post Traumatic Para Articular Ossification of the Knee Joint (' Köhler Pellegrini-Stieda Shadow) Radiology 22 701 1934.
Palmer Ivar Ten Operated Cases of Injuries to the Crucial Ligaments in the Knee Joint, Acta chir Scandinav 79 301 1937
Palmer Ivar On the Injuries to the Ligaments of the Knee Joint Clinical Study Acta chir Scandinav (supp 53) 81 3, 1938.
Phemister D B.: The Causes of and Changes in Loose Bodies Arising From the Articular Surface of the Joint J Bone & Joint Surg 6 278, 1924.
Platt H. Traction Lesions of the External Popliteal Nerve Lancet 2: 612, 1940
Platt, H.: On the Peripheral Nerve Complications of Certain Fractures J Bone & Joint Surg. 10 403 1928
Polacco, E. Free Bodies in the Hip Joint Internat. Abstr Surg 50 456, 1930. (Abstracted from Arch. ital. di chir 24 671, 1929)
Rachlin, Nathan H Pellegrini-Stieda Disease J Bone & Joint Surg 16 716, 1934

Shands, A. R., Jr., Hutchison, J. L., and Ziv, L. Derangements of the Semilunar Cartilages of the Knee. A Clinical and Experimental Study South. M. J 29 1045, 1936.
Shands, A. R., Luck, J. V., Smith, H., and Lacey, H. B. Orthopedic Surgery in the Army Air Forces During World War II. To be published.
Slocum, D B., and Moore, D E.: Posterior Horn Lesions in Meniscal Injury Surg., Gynec. & Obst. 77 87, 1943
Smillie, I. S.: Injuries of the Knee Joint Baltimore, 1946, Williams & Wilkins Co.
Smillie, I. S.: Observations on the Regeneration of the Semilunar Cartilages in Man Brit. J Surg. 31 398, 1944
Smith, A. DeF., and King B. B Injury to Femoral Articular Cartilage by the Medial Meniscus, Surg., Gynec & Obst. 71 679 1940
Smith, S. Alwyn: The Diagnosis and Treatment of Injuries to the Crucial Ligaments, Brit. J Surg 6: 176 1918
Soto-Hall, R.: Traumatic Degeneration of the Articular Cartilage of the Patella, J Bone & Joint Surg 27 426, 1945.
Sutro C. J: Fissures of the Articular Cartilage of the Patella Occurrence in Multipartite Patella, Surgery 19 251, 1946.
Taylor Hermon: Cysts of the Fibrocartilages of the Knee Joint, J Bone & Joint Surg 17 588 1935
Terhune S. R., Eddleman, T S., Thompson, S. B. and Read, B. S.: The Care of the Knee Following Excision of a Meniscus, J Bone & Joint Surg 25 663, 1943.
Voshell, A. F., and Brantigan, O C. Bursitis in the Region of the Tibial Collateral Ligament, J Bone & Joint Surg 26 793 1944
Walmsley, R., and Bruce J Early Stages of Replacement of Semilunar Cartilages of Knee Joint in Rabbits After Operative Excision, J Anat. 72 260 1938.
Watson Jones, R. Fractures and Joint Injuries, ed. 3 Edinburgh, 1943 E. & S. Livingstone.
Zadek, I., and Jaffe, H. L. Cysts of the Semilunar Cartilages of the Knee, Arch. Surg. 15 677 1927

CHAPTER VII

DISLOCATIONS

For the purpose of description dislocations will be classified as (1) fresh or acute (2) recurrent or habitual (3) old unreduced (4) relaxed, and (5) pathologic The methods of manual reduction, employed in the majority of fresh dislocations are not pertinent to this subject, discussion will be limited to the technics of open reduction

FRESH DISLOCATIONS

Fresh dislocations, like fractures, rarely necessitate open reduction. Operation should never be undertaken in uncomplicated fresh injuries until con servative treatment has been given a thorough trial. Even though one may anticipate open reduction, an effort should be made to reduce the dislocation by manual force under no circumstances, however, should undue violence be used In the event such measures prove ineffectual, everything should be in readiness for immediate operation. Tissue is occasionally interposed between the articular surfaces, preventing manual reduction, and must be displaced surgically before proper relations of the joint surfaces can be restored.

Whether the open or closed method is employed reduction should not be delayed pathologic changes take place rapidly increasing the difficulty of the operation and diminishing the prospect of a successful outcome. The im mediate reduction of a dislocation by manual or surgical means, however, does not insure a satisfactory end result Trauma sufficiently violent to dislocate a joint may also damage the articular cartilage so severely or interfere with the blood supply to the bones to such an extent that subsequent degenerative changes and a typical traumatic arthritis develop with incongruity of the joint surfaces and a commensurately painful joint. The patient should always be informed of the possibility of traumatic arthritis following open reduction, particularly of the hip joint. This complication is not induced by open reduction per se In the majority of cases wherein open reduction is required, the dislocation and the complication which prevented closed reduction were produced by excessive trauma further the trauma incident to previous at tempts to effect closed reduction, and to open reduction, add to the original injury sufficiently to account for the latent degenerative changes which may be observed.

Dislocation is often complicated by fracture This may vary from a small avulsion fracture of the insertion of a tendon or ligament to gross fractures with or without comminution of the bone and extreme displacement of the fragments. Frequently either the fracture or dislocation alone might be reduced easily by manual force, whereas together they necessitate operation because of the impossibility of securing proper traction and leverage The most common injury of this type is dislocation of the shoulder with fracture of the surgical neck of the humerus.

Nerve injury associated with dislocation is not uncommon, and may mani fest itself as a complete physiologic block of a peripheral nerve or as a per sistent neuritis. The injury to the nerve usually is in the form of a "stretch

Shands, A. R., Jr., Hutchison, J L., and Ziv, L.: Derangements of the Semilunar Carti of the Knee. A Clinical and Experimental Study South. M. J 29: 1046, 1936.
Shands, A. R., Luck, J V., Smith, H., and Lacey H. B.: Orthopedic Surgery in the Air Forces During World War II. To be published.
Slocum, D B., and Moore, D E.: Posterior Horn Lesions in Meniscal Injury Surg., G & Obst. 77 87, 1943.
Smillie, I. S.: Injuries of the Knee Joint Baltimore 1946, Williams & Wilkins Co
Smillie, I. S. Observations on the Regeneration of the Semilunar Cartilages in Brit. J Surg 31 398, 1944.
Smith A. DeF., and King B B. Injury to Femoral Articular Cartilage by the M Meniscus, Surg., Gynec & Obst. 71 679 1940
Smith, S Alwyn: The Diagnosis and Treatment of Injuries to the Crucial Ligam Brit. J Surg 6 176 1918
Soto-Hall, R. Traumatic Degeneration of the Articular Cartilage of the Patella, J & Joint Surg. 27 426 1945
Sutro C. J: Fissures of the Articular Cartilage of the Patella Occurrence in Multipa Patella, Surgery 19 251, 1946
Taylor Hermon Cysts of the Fibrocartilages of the Knee Joint, J Bone & Joint Surg 588 1935.
Terhune, S. R. Eddleman, T S., Thompson, S. B., and Read B. S.: The Care of the Following Excision of a Meniscus J Bone & Joint Surg. 25 663, 1943.
Voshell, A. F., and Brantigan, O. C. Bursitis in the Region of the Tibial Collateral ment, J Bone & Joint Surg 26 793 1944.
Walmsley R., and Bruce J Early Stages of Replacement of Semilunar Cartilage Knee Joint in Rabbits After Operative Excision, J Anat. 72 260 1938
Watson-Jones, R.: Fractures and Joint Injuries, ed 3 Edinburgh, 1943 E. & S. Livings
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dislocation, the cuneiform bones are prominent, lying on the dorsal surfaces of the metatarsal bones a periosteal elevator is inserted between the bones and the plantar displacement of the metatarsal bones corrected Roentgenograms should be made to verify the position

If the joint, or joints, are unstable, fixation may be accomplished by the use of pins, wires, or screws. The ends of the metal should protrude into the subcutaneous tissues in order to facilitate their removal after six or eight weeks.

After Treatment—A plaster cast is applied from the tip of the toes to the tibial tubercle, the arch being well molded and the toes maintained in a flexed position. A window may be cut to allow for swelling This cast is retained for three weeks. A walking plaster cast which is well molded into the longitudinal arch and maintains the toes in flexion is then applied After four weeks the cast is removed and an arch support is fitted to be worn for three months.

Open Reduction of Dislocation of Midtarsal Joints

In dislocations of the midtarsal joints, the forefoot may be displaced toward the dorsal or plantar surface plantar displacement being observed more often

Technic.—An incision three inches in length is made over the anterolateral aspect of the foot If the forefoot is displaced downward the head of the astragalus is prominent on the dorsum and is easily exposed. Frequently the extensor tendons, and at times the capsule and ligaments of the astragaloscaphoid joint are interposed between the scaphoid and head of the astragalus. The tendons are retracted and a bone skid or elevator is introduced between the astragalus and scaphoid. With traction on the forefoot, the bones are pried into proper articulation. Simultaneously normal relations are restored between the os calcis and cuboid.

After Treatment.—A short right splint is applied, holding the ankle at a right angle The extremity is elevated and hot wet dressings are instituted to allay soft tissue reaction At the end of three weeks the foot is placed in a walking cast which elevates the longitudinal arch and weight bearing is permitted. Eight weeks postoperatively the cast is discarded and weight bearing is continued aided for three months by a metal arch support

Open Reduction of Subastragalar Dislocation

In subastragalar dislocation there is complete displacement of all the tarsal bones from the astragalus, not only at the subastragalar joint, but also at the astragaloscaphoid joint. The displacement may be medial lateral, forward or backward the medial type being more common than the remaining three combined. In extreme lateral or medial displacement, the extensor tendons of the toes, the posterior and anterior tibialis tendons, and the capsule of the ligaments adjacent to the astragaloscaphoid joint may become looped over the head and neck of the astragalus in such a manner as to prevent manual reduction and necessitate open reduction.

Technic.—An anterolateral incision three inches in length is made from just above the ankle joint to the cuboid bone After subperiosteal exposure of the subastragalar and midtarsal joints, the head of the astragalus is cleared

paralysis, or the result of direct trauma to the nerve, rather than to complete rupture In the majority of cases function of the nerve is recovered with time no attempt is made to explore the nerve at operation, therefore, *unless it should be in the immediate operative field* If, however function does not begin to return after a reasonable period of time, the nerve should be explored at the site of the physiologic block. This procedure is described in the chapter on *Peripheral Nerve Injuries (Chapter XI)*

Open Reduction of Dislocation of First Metatarsophalangeal Joint

Dislocation of the first metatarsophalangeal joint is a comparatively rare occurrence. Usually the proximal phalanx is displaced onto the dorsal aspect of the metatarsal bone. The head of the metatarsal bone may penetrate the capsule ventrally and be caught in the fibrous tissue of the capsule or the tendons of the flexor muscles, preventing reduction

Technic.—An incision two inches in length is made through the skin and fascia over the medial aspect of the first metatarsophalangeal joint thus, the head will be exposed if the ventral aspect of the capsule has been penetrated The tendons are retracted laterally and, with a small elevator the head of the bone is guided through the rent in the capsule as reduction is accomplished by slight traction and hyperextension, followed by flexion of the toe. It may be necessary to enlarge the rent in the capsule longitudinally or by a T-cut before reduction can be accomplished. The opening in the capsule does not require closure, as the edges fall together after reduction

After Treatment.—The joint is immobilized in slight flexion for two weeks, by means of a longitudinal malleable metal toe splint. Walking may then be permitted, plantar flexion being maintained by a felt pad placed under the foot behind the head of the first metatarsal bone Use of the splint should be continued at night for a period of four to six weeks, to prevent dorsal contracture of the toe.

Open Reduction of Dislocation of Tarsometatarsal Joints

Any one or all of the metatarsal bones may be dislocated at the tarsometatarsal joints. The bases of the bones are usually displaced dorsally although occasionally displacement occurs toward the plantar surface of the foot. In dislocation of the first and fifth metatarsal bones the displacement may in addition be medial and lateral respectively Proper reduction of these two joints is especially necessary as they are important mechanical factors in weight bearing The following procedure is appropriate in both plantar and dorsal dislocations.

Technic.—An incision three inches in length is made on the dorsal aspect of the foot parallel with the extensor tendon of the third toe extending one inch over each side of the articulation If several of the tarsometatarsal joints are dislocated one incision may not be adequate in this event, additional parallel incisions are made as required The deep tissues are dissected close *to the bone. When the dislocation is on* the dorsal aspect, the proximal extremities of the metatarsal bones are prominent, lying on top of the cuboid and cuneiform bones a blunt elevator is placed in the articulation and the bones are forced into normal position by leverage and traction. In plantar

dislocation, the cuneiform bones are prominent, lying on the dorsal surfaces of the metatarsal bones a periosteal elevator is inserted between the bones and the plantar displacement of the metatarsal bones corrected Roentgenograms should be made to verify the position

If the joint or joints, are unstable, fixation may be accomplished by the use of pins, wires, or screws. The ends of the metal should protrude into the subcutaneous tissues, *in order to facilitate their removal after six or eight weeks.*

After Treatment.—A plaster cast is applied from the tip of the toes to the *tibial tubercle, the arch being well molded and the toes maintained in a flexed position* A window may be cut to allow for swelling This cast is retained for three weeks. A walking plaster cast which is well molded into the longitudinal arch and maintains the toes in flexion is then applied After four weeks the cast is removed and an arch support is fitted, to be worn for three months.

Open Reduction of Dislocation of Midtarsal Joints

In dislocations of the midtarsal joints, the forefoot may be displaced toward the dorsal or plantar surface plantar displacement being observed more often.

Technic.—An incision three inches *in length* is made over *the anterolateral* aspect of the foot If the forefoot is displaced downward the head of the astragalus is prominent on the dorsum and is easily exposed. Frequently the extensor tendons, and at times the capsule and ligaments of the astragaloscaphoid joint, are interposed between the scaphoid and head of the astragalus. The tendons are retracted and a bone skid or elevator is introduced between the *astragalus and scaphoid With traction on the forefoot, the bones are* pried into proper articulation. Simultaneously normal relations are restored between the os calcis and cuboid

After Treatment.—A short night splint is applied holding the ankle at a right angle The extremity is elevated and hot wet dressings are instituted to allay soft tissue reaction At the end of three weeks the foot is placed in a walking cast which elevates the longitudinal arch, and weight bearing is permitted. Eight weeks postoperatively the cast is discarded and weight bearing is continued aided for three months by a metal arch support

Open Reduction of Subastragalar Dislocation

In subastragalar dislocation there is complete displacement of all the tarsal bones from the astragalus, not only at the subastragalar joint, but also at the astragaloscaphoid joint. The displacement may be medial, *lateral* forward or backward the medial type being more common than the remaining three combined. In extreme lateral or medial displacement, the extensor tendons of the toes, the posterior and anterior tibialis tendons, and the capsule of the ligaments adjacent to the astragaloscaphoid joint may become looped over the head and neck of the astragalus in such a manner as to prevent manual reduction and necessitate open reduction.

Technic.—*An anterolateral incision three inches in length* is made from just above the ankle joint to the cuboid bone After subperiosteal exposure of the subastragalar and midtarsal joints, the head of the astragalus is cleared

of all soft tissue obstructions. A bone skid is inserted into the subastragalar joint and the normal anatomic relationship between the os calcis and astragalus, and scaphoid and astragalus, is restored by leverage and traction. If the dislocation is medial, an assistant simultaneously abducts and everts the foot in lateral displacement the foot is adducted and inverted.

After Treatment.—A boot cast is applied and bivalved to allow for post operative swelling After three weeks, a walking boot cast is fitted to be retained for eight weeks. During this period weight bearing is gradually resumed Arch supports should be worn for three months after removal of the cast.



Fig. 221.—*A* Subastragalar dislocation. *B* After open reduction.

Dislocations of the Ankle

True dislocations of the ankle without fracture of the internal or external malleolus or of the anterior or posterior lip of the articular surface of the tibia are extremely rare. Reduction, as a rule, can be accomplished by conservative means. Lateral dislocations may be associated with diastasis of the tibia and fibula, which may require surgical intervention. [See Fresh Fractures (p 391) and Malunited Fractures of the Ankle (p 526)]

Open Reduction of Anterior Dislocation of the Knee

Traumatic dislocation of the knee is observed far less often than other lesions of this joint, though not as seldom as the literature would lead one to assume. In Conwell s series of 300 dislocations of the major joints, seven, or approximately 2.3 per cent, involved the knee.

In anterior dislocation, the tibia is displaced upward and anterior to the condyle of the femur Any of the ligaments may be partially lacerated or severed the anterior cruciate ligament is always ruptured, and often the posterior ligament as well. Not infrequently injuries to the popliteal vessels and nerves are associated.

Regardless of the type of displacement, whether anterior posterior lateral medial or rotary dislocations of the knee may usually be reduced without difficulty by manipulative measures. Rarely the dislocation is of the button hole

type, necessitating open operation. If a dislocation of the knee cannot be readily reduced, the attempt should be abandoned as soft tissue structures will be found interposed between the tibia and the femur, prohibiting removal of the obstruction by closed methods The structures which act as impediments to reduction vary according to the degree and type of displacement. Watson-Jones and Anderson report a case wherein a fold of capsule was caught between the tibial and femoral condyles, preventing complete reduction. In one of our cases, open reduction was required for posterior displacement of the tibia on the femur with internal rotation of the leg on the thigh The technic employed for this case is described below The same principles may be followed for reduction of other dislocations of the knee, according to the position of the articular surfaces.

Technic.—The knee joint was exposed through an anteromedial incision The failure of closed reduction was explained by the fact that the internal ligament was completely torn from the internal condyle of the femur, the medial condyle of the femur had protruded through the medial capsule of the knee joint in a button hole fashion also a large segment of the vastus medialis muscle and the posterior portion of the internal lateral ligament and capsule had been displaced posteriorly around the internal condyle of the femur and lay in the intercondylar notch. Forward traction on the leg at this stage produced a typical button hole like arrangement whereby the structures caught in the intercondylar notch were merely placed on increased tension. Following anatomic restoration of the vastus medialis muscle and other structures which were caught in the intercondylar notch, reduction was easily accomplished. The internal lateral ligament was fixed to the internal condyle of the femur by means of a staple.

Repair of the cruciate ligament is seldom necessary Following the intense periarticular reaction and intra-articular fibrous tissue formation, the joint is usually stable

After Treatment.—Fixation is maintained by means of a cast or splint from the groin to the toes, the knee being held in complete extension. After three weeks, active and passive motion and physical therapy are instituted and walking allowed, with the joint supported by a cage knee brace. No motion is permitted in the brace until one month after weight bearing is resumed

Open Reduction of Posterior Dislocation of the Hip

In posterior dislocations of the hip the head is extruded through the capsule at the lower posterior portion and ascends upon the dorsum of the ilium Closed reduction is successful in the majority of cases. Failure usually indicates that soft tissue structures are looped over the neck, or that the rent in the capsule has contracted around the neck, prohibiting reinsertion of the head into the capsule and acetabulum without surgical intervention

Before undertaking operation, a careful examination should be made to determine the status of the sciatic nerve, as a complete or partial physiologic block of this nerve is a frequent complication of the dislocation.

Technic.—The anterior iliofemoral incision (p 146) or a curved lateral approach (p 150) between the tensor fasciae femoris and gluteus medius muscles are both efficient for reduction of dislocations of the hip A straight

lateral, lateral U or posterior Kocher incision is also applicable although by their use hemorrhage is likely to be excessive and an adequate view of the acetabulum is obtained with difficulty In the presence of fractures of the posterior rim of the acetabulum associated with posterior dislocation of the hip, the approach and technic as advocated by King *is preferable (see below)*

The acetabulum is first exposed by a T-shaped incision and sponged out. By manual movement of the femur the head is located just above and posterior to the acetabulum. The head may penetrate the abductor or short external rotator muscles, and occasionally the sciatic nerve is looped across the anterior surface of the head and neck. With care to protect this nerve, the muscular structures must be maneuvered or dissected from about the head to permit release of the head and neck. Also examination usually reveals a mass of capsule and ligament wrapped about the neck of the femur The rent in the capsule may be contracted about the neck in such a manner that reduction even under direct vision is impossible without enlarging the opening After these obstructions are removed, the head usually may be replaced into the capsule and reduced by upward traction with the hip flexed to a right angle and adducted.



Fig. 122.—*A* Complete posterior dislocation of hip with fracture of portion of head of femur *B*, Two months after open reduction. The loose fragment of bone from the head was removed, but defect not apparent, due to rotation.

After Treatment.—A Thomas splint or the ordinary Buck's extension generally provides adequate immobilization in uncomplicated dislocations. No effort is made to immobilize the hip completely unless the joint is unstable after reduction in the latter event, a long spica cast which holds the hip in abduction may be required. After two weeks, active and passive motion and physical therapy are instituted Walking is permitted at the end of four weeks, and weight-bearing is gradually resumed with the support of crutches.

Stuck and Vaughan feel that in uncomplicated dislocations, patients should remain recumbent until the soft tissue damage is repaired Subsequently the

patient should walk with crutches for from six to twelve months, or until the roentgenogram demonstrates normal anatomy During this follow up period roentgenograms should be made every two to three months for at least twelve months after the injury

The end results are excellent if circulation to the head of the bone is not seriously impaired As the ligamentum teres is always ruptured, circulation from this source is destroyed, and if the main vessel in the posterior capsule is also severed or obstructed secondary degenerative changes may take place in the head These changes cause gross irregularities from sequestration and absorption the constant irritation may result in persistent pain and loss of function. Surgical procedures applicable to this condition are arthroplasty (Chapter XVII) and arthrodesis (Chapter XV) The operation should be chosen according to the contour and state of viability of the head

Neuritis from injury to the sciatic nerve at the time of the dislocation, is not an uncommon sequela and may persist from one to two years. No treatment is of lasting benefit

Open Reduction of Anterior Dislocation of the Hip

Anterior dislocations are classified as pubic obturator and perineal, according to the position assumed by the head of the femur Reduction usually is accomplished by traction in the axis of the deformity and pressure on the head of the femur in the direction of the joint A canvas sling is placed about the upper part of the thigh for exerting lateral traction If reduction by this means is impossible, the anterior dislocation may be converted manually into a posterior dislocation Through an anterior iliofemoral incision, open reduction is then carried out by the technic for posterior dislocations of the hip

Campbell reported one case of perineal dislocation treated by open reduction Roentgenograms revealed the head of the femur displaced into the perineum and the greater trochanter avulsed Manual force succeeded only in changing the position of the head of the femur from the perineal region onto the dorsum of the ilium On the twelfth day following injury open reduction was carried out The short external rotator and abductor muscles were coiled about the neck and head of the femur and the acetabulum was obscured by a dense fascial band After removal of these obstructions, reduction was effected without difficulty

Open Reduction of Posterior Dislocation of the Hip with Fracture of the Acetabulum

In fresh fracture-dislocations of the hip joint the dislocation may ordinarily be reduced by conservative measures the manipulative procedure being identical to that for uncomplicated dislocations. Reduction of the dislocation and fracture should be accomplished as soon as the patient s condition will permit Roentgenographic studies, including stereoscopic anteroposterior views and a lateral view of the acetabulum should then be made to determine the relationship of the head of the femur with the intact acetabulum as well as the accuracy with which the displaced acetabular fragment has been reduced. Occasionally the subluxation or upward and backward displacement of the head of

the femur may be so slight as to be unrecognizable without close inspection and a comparison of the roentgenograms with those of the normal hip

It is essential that the normal anatomy of the hip be restored as nearly as possible. Even the slightest subluxation of the joint or incongruity of the weight bearing surface of the acetabulum is not compatible with good function Further, any incongruity in the acetabular wall or in the head of the femur is certain to produce a degree of traumatic arthritis, regardless of the viability of the head, and any displacement of the head of the femur is soon followed by degenerative changes in the joint.



Fig 223.—Reduction of fracture-dislocation of hip through posterior approach (King and Richards), Skin incised from posterior superior iliac spine to trochanter Gluteus maximus muscle (*A*, *A*) divided in line of fibers, and retracted. Hemostats under piriformis (*C*) and obturator internus and gemelli (*D*) posterior superior iliac spine (*S*), sciatic nerve (*F*) quadratus femoris (*E*) trochanter (*T*) (From King D., and Richards, V J Bone & Joint Surg 23 633 1941.)

King and Richards have listed the indications for open reduction as follows (1) if the lip fragment is large and is not accurately replaced, (2) if the lip fragment is in the acetabulum, (3) if a fragment from the head of the femur lies in the acetabulum in a manner which prevents reduction, (4) if a transverse fracture through the acetabular floor allows rotation of the distal fragment of the innominate bone thereby preventing proper reduction of the head of the femur and presenting an incongruous acetabulum. In reduction of dislocation by manipulation, the lip fragment falls naturally into relatively

normal position as the head enters the acetabulum. If the fragment of the acetabulum is relatively small and narrow little if any of the articular surface is involved and restoration of the anatomic position is unnecessary.

Technic (King and Richards).—The patient is placed in a prone position, as near the edge of the table as possible, so that the hip joint may be flexed if necessary, during the operation. The joint is approached by a posterior incision (p. 149). An excellent exposure of the posterior wall of the acetabulum is provided by division and retraction of the common tendon of the piriformis, obturator internus and gemelli muscles. The retracted muscles protect the



Fig. 224.—Same as Fig. 223. Tendon of piriformis, obturator and gemelli (C, D) divided and retracted medially exposing posterior wall of acetabulum (G). Sciatic nerve (F) protected by muscle bellies (C, D). Gluteus minimus (B), quadratus femoris (E), trochanter (T). (From King, D., and Richards, V.: J. Bone & Joint Surg. 23: 533, 1941.)

sciatic nerve. A right-angle retractor is placed in the pelvis between the greater sciatic notch and the ischial spine, the end of the retractor resting on the intra pelvic surface of the acetabular floor. If required, further exposure is easily obtained by a subperiosteal dissection of the gluteus minimus muscle superiorly. The procedure thereafter depends upon the abnormalities present. As a rule a large triangular segment of bone consisting of the posterior-superior lip of the acetabulum will be found rotated and displaced laterally and forward. This fragment is easily replaced in its anatomic position and fixed with a metal screw. To avoid penetrating the joint the screw is inserted at an oblique angle

upward, roughly toward the middle of the iliac crest. The bone in this area is of sufficient thickness to insure good fixation

If small, and displaced into the acetabulum, the lip fragment is removed. If more extensive including a fairly large segment of the articular surface, the fragment is replaced as described above Chip fractures from the head of the femur which interfere with reduction usually necessitate redislocation of the head of the femur from the acetabulum before removal can be accomplished



Fig. [illegible].—Same as Fig 223, Retractor (*J*) in the pelvis against infrapelvic surface of acetabular floor Fractured posterior rim of acetabulum (*H*) in characteristic position. Head of femur (*L*) silk suture through capsule (*K*) (From King D and Richards, V : J Bone & Joint Surg 23 533, 1941.)

Chip fractures are frequently attached to the ligamentum teres. Fortunately the corresponding defect in the head of the femur is not on the weight-bearing surface and will not be attended by particularly severe arthritic changes. Large fragments from the weight bearing surface of the head are removed and discarded, rather than replaced in position Otherwise, such fragments would certainly undergo aseptic necrosis, would probably not unite with the head of the femur and would be a source of constant irritation in the hip joint.

Fracture through the floor of the acetabulum allows rotation of the distal half of the innominate bone thus producing a definite jog in the articular surface and preventing reduction To correct this discrepancy a periosteal elevator is inserted into the fracture line and the superior end of the distal

fragment is pried back into position In some cases the loose acetabular fragments may be fixed to both the superior and inferior fragments by two screws.

After Treatment.—Immobilization may be maintained by traction a hip spica cast, or by Wilkie boots. Active exercises are begun eight to ten weeks postoperatively the time depending upon the size of the acetabular fragment If the head of the femur has been fractured full immobilization is maintained for at least eight weeks Weight-bearing is permitted after ten to twelve weeks.



Fig 220.—Same as Fig 221. Fragment of acetabulum (H) replaced in anatomic position and held by a screw (From King D and Richards, V J Bone & Joint Surg. 23 533, 1941.)

Open Reduction of Central Dislocation of the Hip

Central dislocation of the hip is produced by the transmission of a force through the head of the femur and consists of a fracture of the acetabulum with intrapelvic protrusion of the head. Injuries to the pelvic viscera are serious complications and may lead to a fatal termination.

In fresh dislocations, reduction is usually accomplished by closed methods Open operation might be indicated, however under two circumstances (1) when the head of the femur becomes caught by the jagged fragments about the osseous aperture in the acetabulum in a manner which prevents disengagement of the head by manipulation and traction and (2) in the presence of a more or less transverse fracture of the acetabulum, without comminution, which fails to fall into place after the dislocation is reduced.

The acetabulum is usually so incongruous and the articular surfaces of the hip joint so traumatized that a traumatic arthritis is inevitable. In the majority of these cases, arthrodesis will eventually be required

Levine reports one case of central fracture of the acetabulum wherein the head of the femur protruded into the pelvis. The femoral head was withdrawn from the pelvis by manipulation and traction, though the inner floor of the frag ments of the acetabulum retained to some extent its former position Seven days after the injury an open reduction was performed to improve the position of the acetabular fragments.

Technic (Levine) —A Smith Petersen incision was made over the anterior half of the crest of the ilium and down over the thigh for a distance of five inches. The soft tissues were detached from the crest of the ilium subperiosteally *from the lateral toward the medial side* *This* dissection was carried downward into the anterior iliac fossa the iliopsoas and iliac muscles being retracted *medially likewise the viscera were retracted toward the opposite side* of the pelvis. The larger fragments of the inner table were replaced manually and when the inner table was tapped with a bone set, the entire area fell into the normal position. As two large fragments tended to become lodged medi ally a stainless steel plate was bent to conform to the contour of the pelvis and inserted over the fragments, spanning the fracture site obliquely from the anterior to the posterior edges and from above downward.

After Treatment.—(See above)

Open Reduction of Posterior Dislocation of the Hip With Fracture of the Neck, Trochanter or Shaft

Posterior dislocations of the hip associated with fractures of the neck of the femur the trochanter or the shaft, are relatively uncommon If one wishes to delve into this subject in detail, he may well read the article by Henry and Bayumi these authors collected all of the cases from the literature up to 1933 and reported 16 dislocations of the hip associated with fractures of the neck of the femur and a similar number associated with fractures of the upper half of the shaft of the femur Subsequently King and Richards, Hart, and others have reported cases.

In view of the rare incidence of this lesion, a detailed discussion of the operative measures which might be applicable to the various types is not war ranted the proposed treatment will be merely outlined. In fracture of the femoral neck associated with dislocation, the head lying as a loose fragment posterior to the hip joint, the consensus seems to be that the head of the femur should be removed and a reconstruction operation, such as the Whitman procedure should be performed. At first glance reduction of the dislocation fol lowed by internal fixation with a Smith Petersen nail, might seem justified. Since a nonviable head and arthritic changes appear inevitable, however one may as well proceed at once to deal with this problem by removing the head.

Hart reports a dislocation of the hip associated with a fracture of the neck of the femur wherein open reduction was of necessity delayed because of con current injuries. Following reconstruction of *the hip by the Whitman method* ossification and calcification developed in the hematoma to such an extent that *a solid bony ankylosis with excellent function ensued*

In dislocations of the head of the femur, associated with comminuted trochanteric fractures open reduction is essential One of us (Boyd) has observed such a case Because of associated injuries, open reduction could not be carried out for six weeks. The head, neck and trochanteric fragment were reduced with considerable difficulty The trochanteric fracture was fixed by means of three Knowles' pins and two wire loops passed around the oblique portion of the fracture



A. B

Fig. 227.—A. Dislocation of head of femur with comminuted fracture of trochanter Open reduction delayed 6 weeks because of severe chest injury B Eight months postoperatively fracture is solid. So far no evidence of aseptic necrosis or marked arthritic change.

Watson-Jones is of the opinion that in dislocations of the hip associated with fractures of the upper half of the shaft of the femur, every conservative means should be utilized to accomplish reduction of the hip by closed methods. He recommends the Stimson type of maneuver wherein the patient lies prone on the table, with the limbs hanging over the edge The head of the bone is forced back into the acetabulum by gravity together with direct pressure. Watson Jones suggests that a Steinman pin or spike be driven into the trochanteric region to aid in reducing the proximal fragment. If these procedures are not successful both the dislocation of the hip and the fracture of the shaft may be reduced by open operation. After exposure of the fracture of the shaft, instrumental manipulation of the proximal fragment may serve to reduce the dislocation as well as the fracture If actual exposure of the hip can be avoided the danger of the aseptic necrosis of the head will be reduced.

ASEPTIC NECROSIS OF THE HEAD OF THE FEMUR FOLLOWING DISLOCATION OR FRACTURE-DISLOCATION OF THE HIP

The end results of dislocations of the hip are usually excellent, provided circulation to the head of the bone is preserved In fracture-dislocations, the added trauma or incongruity of articular surfaces affects adversely the end result. Since the ligamentum teres is always ruptured, circulation from this



Fig 228.—*A* Dislocation of hip. *B* Aseptic necrosis of head of femur eight months after reduction, as evidenced by sclerosis and increased density of head narrowing of joint space and incongruity of articular surfaces.

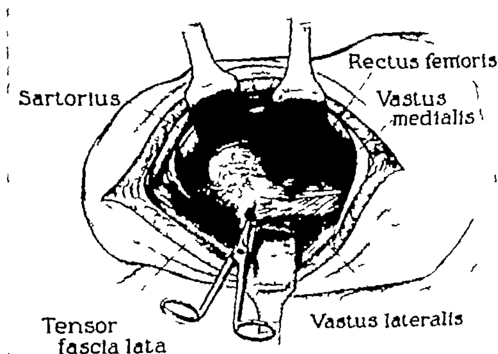


Fig 229.—Muscle flap operation to improve circulation to head of femur Hip joint exposed by anterior iliofemoral incision. Flap of vastus lateralis muscle being freed for transplantation. (From Stuck, W G and Hinchey J J Surg Gynec. & Obst. 78 160, 1944.)

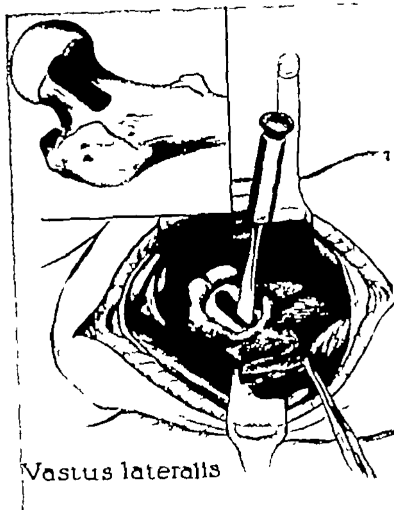


Fig. 230.—Same as Fig. 229. Slot prepared on anterior surface of neck of femur to receive muscle transplant. (From Stuck, W. G. and Hinchey, J. J.: Surg., Gynec. & Obst. 73: 160, 1941.)

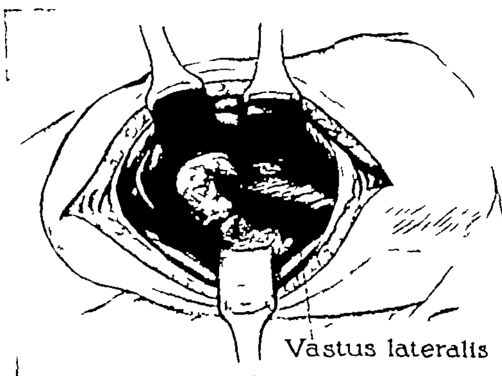


Fig. 231.—Same as Fig. 229. Flap of vastus lateralis muscle sutured into slot in neck of femur. Position maintained by sutures through capsule and adjacent ligaments. (From Stuck, W. G., and Hinchey, J. J.: Surg., Gynec. & Obst. 73: 160, 1941.)

source is destroyed If the main vessel in the posterior capsule is destroyed or obstructed *revascularization may be incomplete and secondary degenerative* changes may take place in the head of the femur These changes cause gross irregularities from sequestration and absorption, and the consequent irritation may lead to persistent pain and loss of function.

Less commonly these same changes are observed from trauma or idiopathic origin without fracture or dislocation of the hip Consequently, it is possible that the gross necrosis following dislocation is not always due to interruption of the posterior capsular vessels alone, but to an indeterminate traumatic vascular disturbance of some or all of the vessels supplying the head.

Theoretically, it would be desirable *for patients to avoid bearing full weight* for perhaps six months to a year following dislocation, or until the viability of the head of the femur can be determined. This, however is not feasible, especially in adults Few patients would be willing to walk on crutches for so long Further it has not been proved to our satisfaction that a lack of weight bearing will be effective in preventing an aseptic necrosis of the head of the femur Also even if aseptic necrosis of the head of the femur were anticipated beforehand, three to five years might be required for complete revascularization of the head after the lapse of this time, it is extremely doubtful whether a satisfactory joint would be preserved Prevention of weight bearing with crutches, therefore cannot be considered a practicable prophylactic measure in adults. In children, rest in bed for an indefinite time i.e. one or two years might reasonably be enforced, as the prospect of regeneration of the head of the femur in these patients is fairly favorable.

The two procedures most often employed for coxa malum deformity, namely mold arthroplasty and arthrodesis, are applicable to aseptic necrosis of the head of the femur following dislocation. Since the entire head is usually involved and must be excised the technic combines the principles of the Whitman reconstruction operation with mold arthroplasty Transplantation of the greater trochanter *provides increased stability and obviates impingement by the cup*

Arthrodesis provides a stable, painless member, but with the obvious disadvantages attendant upon a stiff hip A modification of the Watson-Jones technic is preferable. Because of the avascularity of the head, at least a year will be required for solid bony ankylosis of the hip after operation. In order to preserve function in the knee joint, some form of internal fixation must be utilized. It is particularly desirable that the relatively vascular ilium and trochanter be bridged by an iliac graft. A fibrous ankylosis is not adequate, even though a three-flanged nail is inserted stress and strain will eventually loosen the nail and deformity will recur when motion is resumed Only after bony ankylosis is complete may one consider the case successfully concluded.

Potts and Obletz have suggested that if the aseptic necrosis of the head of the femur is discovered early multiple drilling may be of some value in that the normal process of revascularization is thus facilitated. Clinical experience has shown that this procedure is of no real or lasting value.

Stuck has described a muscle-flap type transplant which he has used in 27 patients in all but one, the relief of pain was striking He has applied this procedure to aseptic necrosis following dislocations, Perthes' disease slipped femoral epiphyses old malunited fractures, coxa malum, and any condition of

the hip wherein chronic arthritis is associated with an ischemia of the head of the femur This procedure might be worth a trial It has not been generally adopted however and we have had no experience with it (Figs 229 231)

Technic (Stuck)—The hip joint is exposed through an anterior iliofemoral incision The capsule is incised longitudinally bringing into view the head, trochanter, and neck. A slot about 1 × 4 cm. is then cut in the neck of the femur from the base of the head to the trochanteric region The medial half of the vastus lateralis muscle is next dissected free, its end is transplanted into the slot in the neck of the femur, and the flap is fixed in this position by several wire sutures. The vastus lateralis should be inserted into the slot without tension to accomplish this, the flap must be dissected free for at least five or six inches

DISLOCATIONS OF THE SPINE

The technics of reduction of dislocations of the spine are described in the section on Fracture-Dislocations (pp 453, 458)

UPPER EXTREMITY

Only the surgical technic for reduction of dislocations of the head of the radius, semilunar bone, finger joints and metacarpophalangeal joint of the thumb will be described Uncomplicated dislocations of the shoulder and elbow require open reduction in a negligible number of cases the operations, however resemble those for unreduced dislocations of these respective joints, but are much less difficult. Fracture-dislocations of the shoulder are described in the chapter on Fractures.

Open Reduction of Dislocation of the Head of the Radius

In simple dislocation of the head of the radius, the displacement is always anterior and manual reduction is easily effected as the orbicular ligament is ruptured or displaced however the spasmodic contracture of the biceps muscle interferes with maintenance of the normal position, and the dislocation may recur habitually on extension of the elbow Unless reduced, the head of the radius mechanically limits flexion of the joint.

Technic.—An incision is made over the posterior aspect of the head of the radius (p 183) the head is exposed, and the orbicular ligament identified. The dislocation is reduced and the ligament united with No 0 catgut suture If suture is impossible a fascial transplant, one-half inch in width and four inches in length is taken from the outer aspect of the thigh. The posterior surface of the ulna is next exposed through an additional incision two inches in length and a hole is then drilled transversely through the ulna one half inch distal to the level of the head of the radius. The strip of fascia lata is passed through this tunnel and around the neck of the radius, and sutured together at the ends. In this manner a new orbicular ligament is created.

After Treatment.—To prevent recurrence of the dislocation, the joint is immobilized in a right angle elbow splint midway between supination and pronation and so maintained for a period of three weeks. Active and passive motion and physical therapy are then instituted

Although partial recurrence is not uncommon even with care normal function is compatible with slight displacement

Open Reduction of Dislocation of the Head of the Radius with Fracture of the Upper Third of the Ulna (Monteggia Fracture)

The technic of reduction of this fracture-dislocation is described in the chapter on Fractures.

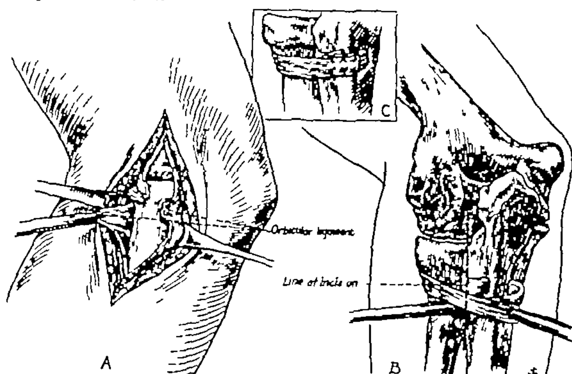


Fig. 212.—Dislocation of head of radius. A Rupture of orbicular ligament. In some cases, suture of this ligament is sufficient. *B,* Construction of an artificial obicular ligament with strip of fascia lata. *C* Operation completed.

Open Reduction of Anterior Dislocation of Semilunar Bone

MacAusland gives the following indications for open reduction in perilunar dislocations of the carpus on the lunate bone or in the volar dislocations of the lunate bone from the carpus (1) dislocation associated with extensive damage to the joint structure or to the median nerve (2) dislocations which have been treated by manipulation (3) dislocations of more than two weeks duration. Where reduction of the lunate bone appears possible, he prefers a dorsal incision to the anterior exposure for the following reasons (1) the *dorsal approach leads directly to the lunate bone, avoiding tendons, vessels, and* nerves, (2) the division of a ligament is unnecessary (3) healing takes place *more readily and the formation of a keloid on the wrist is less likely than in an* anterior incision.

If the dislocation is of more than two weeks duration, or if some difficulty in mobilizing and reducing the semilunar bone is anticipated, or if there is a possibility that excision of the bone may be necessary the anterior approach as described by Mahorner and Mead, should be used.

Technic (MacAusland).—An incision approximately two inches in length is made on the dorsum of the wrist the fascia is divided, and the cavity of the lunate bone is exposed. Traction is applied on the hand and the cavity cleaned for reception of the bone A blunt dissector is then inserted on each side of the os capitate and the lunate bone being used as a fulcrum of leverage the

carpal bones are brought into position This maneuver is combined with manipulation of the wrist in much the same manner as reduction of a Colles' fracture The remnants of the dorsal radiocarpal ligaments are sutured

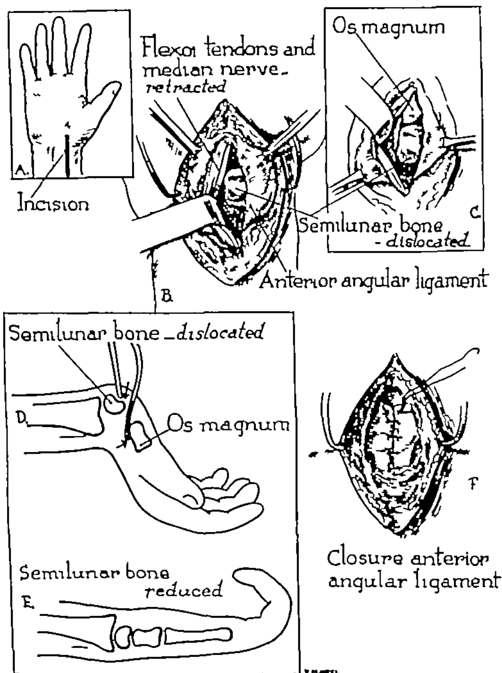


Fig 231.—Reduction of dislocation of semilunar bone through anterior incision (From Mahorner H R., and Mead W H. Surgery 5 249 1939)

Technic (Mahorner and Mead) —A two-inch incision is made on the anterior aspect of the wrist between the tendons of the palmarus longus and flexor carpi radialis muscle The anterior annular ligament is incised, and the flexor sublimus and profundus tendons together with the undisclosed median nerve are retracted to the ulnar aspect of the wrist This brings into view the glistening articular surface of the dislocated semilunar bone. The proximal end of the os magnum bone is exposed by longitudinal incision of the ligamentous

Technic.—An incision two inches in length is made over the radial aspect of the joint, exposing the articular surfaces of the phalanx and metacarpal bone. The base of the phalanx lies on the dorsal aspect of the head and neck of the metacarpal bone and the latter protrudes through the anterior capsule. The tendons of the flexor pollicis brevis muscle are disengaged and retracted forward releasing the head of the metacarpal bone As traction is applied and the thumb flexed the head is pushed through the rent in the capsule and reduction completed.

After Treatment.—The thumb is held in moderate flexion by a metal splint. After ten days, the splint is removed and active and passive motion begun

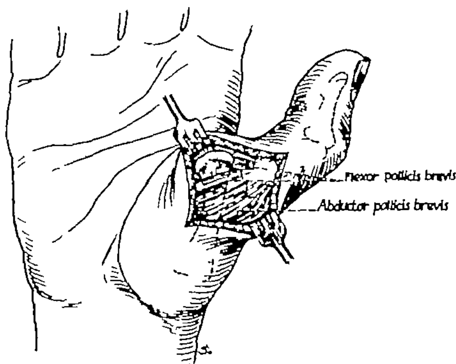


Fig. 135—Dislocation of metacarpophalangeal joint of thumb. Displacement of head of metacarpal bone through flex r muscle frequently necessitates open reduction.

Open Reduction of Finger Joints

The middle and distal finger joints of the second to fifth fingers, inclusive, may be the site of a button hole type of dislocation which is irreducible by closed methods. The injury is similar to the button hole type of dislocation which takes place in the metacarpophalangeal joint of the thumb If one is unable to reduce the dislocation of the finger joint with little effort on the first or second attempt, further manipulative procedures should be abandoned otherwise, the structures will be unduly traumatized. A longitudinal tear through the anterior capsule of the joint will usually be found. The distal end of the proximal bone protrudes through this button hole slit the hole encompassing the base of the neck of the bone thus, traction and manipulation only increase the grip of the capsule on the bone. In some cases, a redundant fold of the posterior capsule of the joint may be interspersed between the bones, giving the impression that reduction is adequate. After traction is relieved however the dislocation recurs.

Selig and Schein report one case wherein closed reduction was prevented by an engagement of the flexor digitorum profundus tendon between the dislocated bones.

Technic.—The dislocation is exposed through a lateral incision The button hole type rent in the anterior capsule which encompasses the distal end of the proximal bone is enlarged by further extensions of its length or by a short transverse incision of the capsule The head of the bone may then be guided through the capsule without difficulty by the use of the ordinary maneuvers. Repair of the rent in the anterior capsule is unnecessary

After Treatment.—The joint should be maintained in moderate flexion by a dorsal plaster splint for a minimum period of three weeks. Thereafter, active exercises are begun. There is little danger of recurrence of the dislocation. Roentgenograms should be made at the end of one week to check the position of the bones.

Following open reduction of any dislocation of a finger joint, limitation of motion is a distinct possibility and should be explained to the patient before operation The success of the procedure will be proportionate to the degree and number of preoperative manipulative methods attempted and to the time which elapsed between injury and operation

RECURRENT OR HABITUAL DISLOCATIONS

Recurrent or habitual dislocations of any joint may follow one or more acute traumatic dislocations, the immediate cause being defective repair of the defect by fibrous tissue Deranged anatomic contour or alignment of congenital, traumatic or other origin, congenital laxity of the joint, and deficiency of muscle power may be predisposing factors. Rupture of the attachments of muscles and ligaments and their reattachment at abnormal points impair the function of the muscles and the integrity of the ligaments Also the separation of a portion of the articular surface may alter the plane of the joint to such an extent that slight force may cause recurrence of the dislocation. The tendency to displacement may be so great as to permit only a limited range and the patient will protect the joint by unconsciously controlling motion beyond this range.

Recurrent Dislocation of the Ankle

When the foot is forcefully inverted the anterior and middle bands of the external lateral ligament of the ankle joint maintain the astragalus in its normal relationship with the ankle mortise When these structures are avulsed and the foot and ankle forcefully inverted, a definite sulcus may be palpated at the anterolateral aspect of the ankle joint. The clinical findings may be corroborated by roentgenograms. If the avulsed external lateral ligament does not heal properly the ankle mortise may become unstable in this event, inversion of the foot will give rise to a recurrent luxation of the astragalus on the ankle mortise. With few exceptions, this condition may be controlled by conservative measures. Watson-Jones however states that in a large series of cases, he has found reconstruction of the external lateral ligament of the ankle joint necessary and satisfactory

Technic (Watson-Jones).—A lateral incision is made over the posterior border of the lower third of the shaft of the fibula, around the tip of the external malleolus and forward onto the lateral aspect of the foot. The peroneus brevis tendon is freed from its muscular attachment proximally, the muscle fibers being sutured to the peroneus longus tendon. Distally, the peroneus brevis tendon is released as far as the external malleolus. The annular fibers are not disturbed. A tunnel of appropriate size for the tendon is created through the fibula in an anteroposterior direction approximately one inch above the tip of the malleolus. With the drill in a vertical position, a hole is drilled through the outer margin of the neck of the astragalus immediately in front of the articular surface, the drill emerging in the roof of the sinus tarsi. A third hole is then drilled in the extreme tip of the external malleolus from the anterior aspect in an upward and backward direction. Thereafter, the tendon is guided through the first hole in the external malleolus from posteriorly forward, thence through *the second set of holes in the astragalus from above downward and, finally,* backward through the hole in the tip of the malleolus. The end of the tendon is then sutured to the periosteum on the posterior aspect of the external malleolus.

After Treatment.—The foot is immobilized in a cast from the toes to the tibial tubercle for a period of eight weeks. After the second or third week, weight-bearing is permitted in a walking cast.

Two difficulties may be encountered in this procedure: in the process of drilling the roof of the tunnel may be cracked; the tendon may be too short.

Recurrent Dislocation of the Patella

Dislocation of the patella practically always is lateral. Trauma superimposed upon some abnormality of the structures about the knee is responsible for recurrence of the dislocation. Congenital laxity of the medial capsule, knock knee, abnormal *flattening of the articular surface of the outer condyle* of the femur and the opposing articular surface of the patella, or the insertion of the patellar tendon farther lateral on the tibia than normal are contributing factors.

Surgery is always advisable after repeated recurrences. Not only does the patient become apprehensive, fearing to use the knee, but permanent damage will accrue to the joint if the dislocation continues to recur. A typical osteo-arthritis with extensive scarring of the articular cartilage and consequent progressive impairment of function will eventuate.

The majority of operations for recurrent dislocations of the patella are based upon two principles: (1) the establishment of a straight quadriceps mechanism; (2) the creation of a check ligament, either at the level of the patella medially or from the patella distally and medially. For the sake of brevity older technics still in common usage have been eliminated from the present discussion.

No one particular surgical procedure is applicable to all types of recurrent dislocations of the patella. In middle-aged individuals with a straight quadriceps mechanism and a patella which rarely becomes dislocated, the Campbell operation is suitable. The advantage of this procedure lies in its simplicity

all material utilized is available through the one incision Since the bony attachment of the patella is not disturbed motion may be instituted early Prolonged immobilization is unnecessary and convalescence is relatively short In adults who have a minor degree of valgus, the Goldthwait operation may be combined with the Campbell procedure thus creating a check ligament at the level of the patella and correcting any mild discrepancy in the alignment of the quadriceps mechanism, as well as creating a check ligament distally In the presence of more or less constant mild subluxation and an occasional complete dislocation in an adult chondritis of the patella may be associated, and may necessitate patellectomy together with the above procedure, or in combination with a Hauser operation as described below

For a moderate or marked valgus quadriceps mechanism the Hauser operation, whereby the tibial tubercle is transplanted medially and distally, provides satisfactory correction Occasionally, the Campbell and Hauser procedures are combined The Hauser operation is applicable to a large group of recurrent dislocations of the patella. The rather prolonged immobilization and convalescence are of little consequence in the adolescent and younger adult groups.

For recurrent dislocations of the patella associated with a valgus deformity of the knee, some authors advise osteotomy alone Unless the valgus is extreme this is unnecessary and in any case, its use should ordinarily be limited to children or adolescents

Dislocations, either congenital or secondary to transplantation of the biceps femoris tendon to the patella are not pertinent to this chapter (see Congenital Dislocations of the Patella Chapter XXV)

Technic (Campbell) —A five inch medial incision is made parallel to the quadriceps muscle, the patella and patellar tendon down to the capsule of the knee joint Beginning at a level with the articular surface of the tibia, a strip of capsule five inches in length and one-half to one inch in width is removed and left attached above In all operations for recurrent dislocation of the patella, the joint should be exposed sufficiently for thorough inspection in order that any loose bodies not visible in the roentgenogram may be found. After inspection a digital examination should be made if necessary

The cut margins of the capsule are closed, thus taking up all undue slack and tightening the internal portion of the capsule, the pedicled flap being left free A scalpel is passed from side to side through the quadriceps tendon just above the patella. Through this tunnel a hemostat is inserted from without inward and the end of the flap is grasped and carried through the tendon to the outer side The flap is then reflected medially over the anterior surface of the quadriceps tendon and the free end is stitched to the soft tissues in the region of the adductor tubercle of the femur primarily the attachment of the adductor magnus tendon.

After Treatment. —The extremity is immobilized in a gutter splint. At the end of two weeks active and passive exercises and physical therapy are begun. In the majority of cases, weight bearing is begun three weeks after operation, with the aid of crutches.

Technic (Goldthwait) —An incision is made over the patellar tendon and carried to one inch below the insertion. The tendon is split longitudinally and the outer half detached from the tibia the detached portion is passed beneath

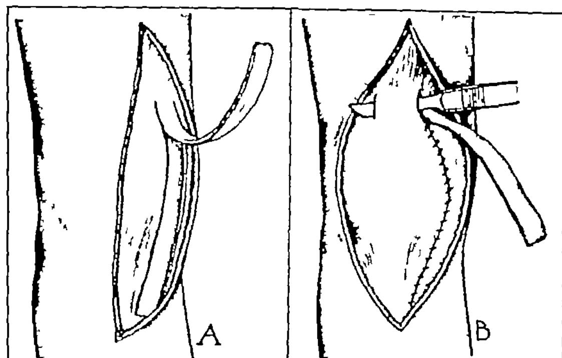


Fig. 236.—Operation for recurrent dislocation of patella (Campbell) *A* Dissection of strip of capsule and tendon, leaving base attached proximally *B* Defect in capsule closed. Tunnel created transversely through quadriceps tendon.

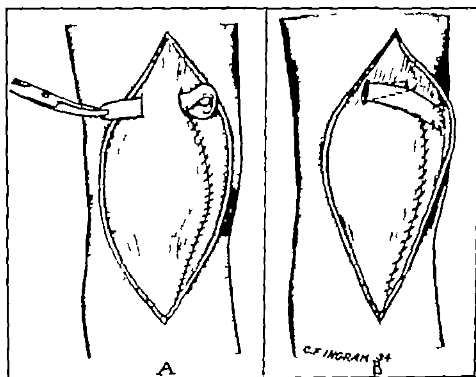


Fig 237.—Same as Fig. 236. A, Strip passed through quadriceps tendon from within outward. *B* Reflected medially and anchored to soft tissue in region of adductor tubercl

the inner half and inserted into the inner aspect of the tibia preferably into the insertion of the sartorius muscle

The Goldthwait procedure established a precedent, namely transplantation of the patellar tendon Davis, Parker, MacAusland, Sir Robert Jones, and many others have devised technics based upon this operation The most recent addition to the list is a procedure described by Hauser wherein the attachment of the patellar tendon is severed and is transplanted to a point lower and more medial on the tibia Hauser states that by this means the normal pull of the quadriceps muscle from origin to insertion is re established and the patella is replaced into its normal groove and in normal relation to the knee The tibial tubercle should not be transplanted so far distally as to be placed under tension This adds immeasurably to the possibility of displacement of the tibial tubercle before healing is complete and prolongs the period of convalescence.

For fixation of the transplanted tibial tubercle, Bosworth and Thompson suggested a three-hole plate Two screws are passed through the transplanted tibial tubercle and the distal end of the plate is anchored to the tibial shaft by a third screw

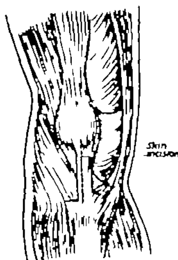


Fig 223.—Goldthwait operation for recurrent dislocation of patella Patellar tendon split lateral half transplanted medially

Technic (Hauser) —An incision is made along the anterolateral aspect of the knee joint extending to a point in the midline one half inch below the tibial tubercle. The patellar tendon is dissected free to its insertion and removed intact with a block of bone one half inch square. The entire lateral side of the patella is then freed by division of the fascia down to the capsule Dissection is carried proximally along the lateral border of the quadriceps tendon well up into the area of the fascia lateral to the vastus muscle and the fascia is divided to the synovial membrane. The joint is not opened the patella may now be drawn medially The patellar tendon is pulled distally and to the medial aspect of the tibia until the patella lies in its normal position between the condyles of the femur A bony block one half inch square is removed at this point and the attachment of the patellar tendon is countersunk into the space thus created Fixation is secured by sutures through the

periosteum *The second graft is fitted into the space at the tibial tubercle.* Three sutures of chromic catgut are placed into the periosteum and the inner side of the patellar tendon to insure further its medial position. (Fixation by sutures through the periosteum only is insecure. A Vitallium nail or screw would provide a firmer fixation of the transplanted tendon and perhaps permit earlier active motion.)

After Treatment.—Fixation is maintained by a plaster cast for ten to fourteen days. Four weeks postoperatively walking is permitted with the knee extended At the same time, gentle motion is instituted, but free flexion is not allowed for six weeks.

Hauser states that a technic similar to this has been employed by Henderson though not published.

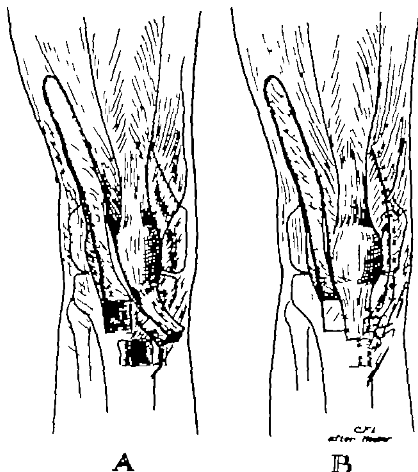


Fig 239 —Hauser operation for recurrent dislocation of patella. *A* Incision of lateral fascia and vastus lateralis muscle. Tendon freed and bony attachment removed. B, Attachment of patellar tendon countersunk in corresponding defect distal and medial to original attachment. Medial fascia and capsule reefed. (Redrawn from Hauser Ldw Surg Gynec., Obst. 66: 199 1938.)

Recurrent Dislocation of the Temporomandibular Joint

Mayer states that one should distinguish between two lesions which occur in the temporomandibular joint (1) true dislocation and (2) abnormality or internal derangement of fibrocartilage He has observed five patients with recurrent slipping of the temporomandibular joint and has operated upon four of these Three had a genuine recurrent dislocation, the condyle having slipped forward over the eminentia articularis the temporal fossa was ex

tremely shallow To correct this situation a bone block operation similar in principle to that used in genu recurvatum and drop foot was employed

Technic (Mayer) —Under local anesthesia, a two-inch horizontal incision is made along the zygomatic process almost to the external auditory meatus, thence continued upward and backward over the base of the pinna of the ear (Burdick incision) The pinna of the ear is turned downward to expose the zygomatic process from its base posteriorly to a point anterior to the temporomandibular joint The superior temporal vessels, which run vertically just anterior to the ear are divided the superficial nerve being retracted The joint is exposed by removal of one inch of the zygomatic process. After incision of the capsule the patient is instructed to open his mouth in order that the true lesion may be accurately observed The resected portion of the zygomatic process is utilized as a bone block being inserted into a groove just anterior to the eminentia articularis. The groove should be approximately one-eighth inch in depth and in order that one half the graft may project downward should be only one half inch in length The edges of the groove are made slightly oblique that the graft may be morticed into position

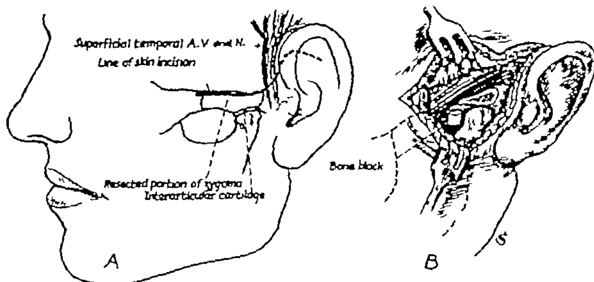


Fig. 240.—Mayer operation for recurrent dislocation of temporomandibular joint. A, Exposure by Burdick incision. B Bone graft from zygoma mortised into temporal bone just anterior to eminentia articularis. (Redrawn from Mayer Leo J Bone & Joint Surg. 13: 889 1933)

After Treatment.—A plaster helmet is applied and retained to prevent motion of the jaw until the graft is healed in position This usually requires four to six weeks.

Recurrent Dislocation of the Shoulder

The shoulder more than any other joint, is subject to recurrent dislocation. With a few exceptions, the displacement occurs anteriorly and is of the subcoracoid type. The most important treatment of course, is prophylaxis, i e. reduction of the first dislocation immediately after the injury, followed by an adequate period of immobilization After repeated dislocations, operative treatment is necessary

The surgical procedures may be classified according to their mechanical objectives, as follows (1) insertion of accessory ligaments by plastic pro-

cedures or by free transplants, (2) plastic procedures on the capsule ligaments and tendons (3) transplantation of bone for the purpose of increasing the efficiency of the glenoid cavity

Until the development of the Henderson and similar technics, many of the operations described for recurrent dislocation of the shoulder were unsuccessful in a relatively high percentage of cases. Subsequently Nicola described a procedure which has also proved successful

In 1938 Bankart published a classic article on recurrent dislocation of the shoulder which established an epoch so far as the true understanding of this lesion and its treatment is concerned In this article Bankart contended that all previously described operations were based upon erroneous ideas that they were attempts to deal empirically with the shoulder and ignored the actual pathology which was the basis of this lesion



Fig 241—Defect in posterior articular surface of humeral head approximates glenoid fossa on abduction and external rotation of arm, thus, normal locking effect of convex surface of head is lost. (From Bost, F C. and Inman, V T J Bone & Joint Surg., 24: 306, 1942.)

Bankart recognized two types of dislocations. He pointed out that the ordinary traumatic dislocation produced by a fall on the abducted arm merely forced the head of the humerus by leverage to the lowest and weakest point of the capsule between the subscapularis and triceps muscles. In these cases, the capsule always healed readily and no further trouble could be anticipated. On the contrary in recurrent dislocations of the shoulder it was his contention that the injury was of an entirely different character namely that by a fall either directly on the back of the shoulder or on the elbow the head of the humerus is forced forward out of the joint by direct force thereby shearing off the fibrous or fibrocartilaginous glenoid ligament from its attachment to the glenoid this detachment involves practically the whole of the anterior half of the glenoid margin Since the capsular attachment, does not heal readily or at all, a permanent defect remains through which the head of the humerus can pass forward over the anterior margin of the glenoid cavity with little difficulty

Bankart provided the key to the present concept of the pathologic changes associated with recurrent dislocation of the shoulder when he observed the detachment of the labrum glenoidale from the anterior aspect of the glenoid rim This, however is not the sole essential lesion associated with recurrent dislocation of the shoulder Bost and Inman have admirably summed up the pathologic picture from anatomic studies and from clinical experience gained in performing Bankart operations (1) the labrum glenoidale and the anterior capsule of the shoulder joint are detached (2) a defect is present in the posterior lateral portion of the head of the humerus, and (3) the glenoid rim is either eroded or fractured Under these circumstances, the head of the humerus is supported only by the shallow concavity of the glenoid fossa the detached labrum and capsule offering no resistance to any dislocating force The normal locking effect of the convex surface of the head is lost as the defect in the humeral head approximates the glenoid fossa on abduction and external rotation of the arm

Recent statistics would indicate that in cases with a defect in the posterolateral surface of the humeral head, recurrent dislocation of the shoulder may occur in the absence of a lesion in the glenoid labrum. Adams states that such a defect was present in all cases in which at operation no defect in the glenoid labrum was found *He further points out that the defect in the humeral head* is not visible in the roentgenograms unless the films are taken with the humerus internally rotated 60 to 70 degrees To visualize the defect it may be necessary to take several roentgenograms with the humerus internally rotated between 50 to 80 degrees. Contemporary literature stresses the importance of this defect We are unaware of any surgical method for primary repair of this pathology As long as it exists, dislocation may recur following repair of the capsule and labrum unless external rotation is partially and permanently restricted

Of the more than 150 technics devised for recurrent dislocation of the shoulder there is not an operation that measures up to all of the requirements, or is universally satisfactory

Henderson in 1943 reviewed the results of 55 operations performed at the Mayo Clinic, wherein the technic originally described by him and entitled Tenosuspension ' as described below was utilized. He has summed up the pros and cons in regard to the Bankart operation versus other, simpler procedures as follows that, if Bankart were correct (and his observations seemed to have been made carefully and to have been substantiated by others) a general adoption of the operation would be the logical course, since the primary and fundamental pathologic condition responsible for recurrent dislocation is attacked he points out however that the Bankart procedure is more or less formidable and that good results may be obtained following other, simpler operations which do not attack the primary pathology Of his series of operations, the results were good in 94 per cent The same logic may be applied to the Nicola operation which is likewise a simpler procedure than the Bankart operation

Bost and Inman point out certain technical disadvantages of the Bankart procedure namely first, the labrum glenoidale is sometimes frayed or relatively nonexistent, and its replacement is not always possible second the capsule and

labrum are sutured to the deeply placed glenoid rim with considerable difficulty finally, the structure are sometimes poor or thinned out, forming a relatively large defect which is not easily eradicated.

In reviewing the literature in 1938 Hobart observed the following end results of a substantial series of cases With 132 Nicola operations, there were 8 recurrences with 41 tenosuspensions, there was one recurrence with 17 fascial suspensions, no recurrence 9 Roberts' operations, no recurrence 7 bone block operations, no recurrence 27 anterior capsule repairs, i e., Bankart operations, no recurrence 2 combination operations, without recurrence and with 43 Clairmont Ehrlich operations 14 recurrences.

Adams in a review of 159 operations for recurrent dislocation of the shoulder among members of the Royal Air Force offers the following end result study With 59 Nicola operations, there were 21 recurrences with 18 Bankart operations, one recurrence 37 Putti Platt operations, two recurrences.

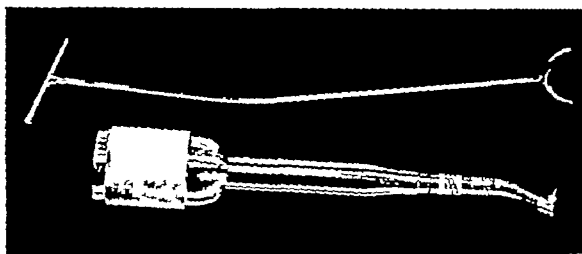


Fig. 212.—Special instruments for Bankart operation Contra-angle dental drill designed to fit a Luck saw Special retractor facilitates exposure of glenoid.

In the subsequent section four operative technics will be described the Bankart and Putti Platt operations, and the Nicola and Henderson operations. These procedures are representative of the more or less opposing schools of thought. The first group represents a more fundamental attack on the pathology is a more difficult technical procedure, and leaves the patient with a slight restriction of motion. The second group is simpler to perform ordinarily provides a normal range of motion, but is attended by a higher percentage of recurrence of the dislocation

The Nicola operation is the simplest of the four for recurrent dislocation of the shoulder and in our hands has been relatively satisfactory for civilians. Until some of the technical details of the Bankart procedure are modified, we feel that the Nicola operation is preferable for adults engaged in sedentary occupations In view of the statistics of the results of the Nicola operation in patients in the military services, however it seems probable that despite the rather more exacting technic of the Bankart (or Putti Platt) operation, it is preferable for young patients and for those who may wish to engage in strenuous activities or athletics.

In carrying out the Bankart procedure it is necessary that proper instruments be available particularly a soup ladle type of retractor and a contra angle dental drill

As an alternative to make the holes through the glenoid the capsule may be approximated to the raw surface by means of staples nails or short screws.

If one encounters difficulty in repairing the defect in the capsule by the Bankart procedure several alternatives are available (1) the capsule may be plicated over the soft tissue on the front of the glenoid and the subscapularis also overlapped and plicated with the joint in moderate internal rotation (Putti Platt) (2) the defect may be covered with fascia lata (3) a Nicola operation may be carried out, or (4) a bone graft may be inserted into the anterior edge of the neck of the glenoid

Bankart Operation (Technic of Cave and Rowe)—The skin is incised along the outer third of the clavicle in a medial direction to the level of the coracoid thence distally along the medial border of the deltoid muscle. The interval between the pectoralis major and the deltoid muscles is developed the cephalic vein being retracted toward the midline The origin of the deltoid muscle is reflected from the clavicle and retracted laterally This exposes the coracoid process with the attachments of the short head of the biceps, the pectoralis minor and the coracobrachialis muscles A hole one-eighth inch in diameter is drilled into the longitudinal axis of the coracoid process for a distance of one inch This facilitates final reattachment of the bony tip with its attached muscles. The coracoid process is then divided with an osteotome, and the tip with its muscle attachments retracted medially and downward, thereby eliminating the excessive tension that is necessary for exposure without division of the coracoid. Further the possibility of injury to the musculocutaneous nerve from retraction is eliminated With the shoulder in external rotation the subscapularis tendon is identified. The process of separating the tendon from the capsule and dividing it must be carried out carefully The lower border of the tendon is first identified by a plexus of veins. The latter are divided and ligated. With a periosteal elevator or blunt dissector the interval between the tendon and capsule is defined and developed. Blunt dissection is carried laterally to the musculotendinous junction of the subscapularis with the capsule The mesial portion of the tendon is secured with two heavy silk sutures, the tendon divided and allowed to retract By palpation the anterior rim of the glenoid can be felt through the capsule Usually a defect in the capsule presents itself. For exposure of the joint the capsule is incised vertically about one-fourth inch lateral to the glenoid rim This incision is approximately two inches in length By this procedure the mesial segment of the capsule is sufficiently long to overlap and provide for capsular repair Subsequently the margin of the glenoid is scarified with an osteotome or curette Holes are then made in the bony rim of the glenoid by means of a pointed, curved spike (or dental drill) With the shoulder at 135 degrees abduction and in 10 degrees of external rotation the lateral segment of the capsule is sutured to the freshened surface of the glenoid the mesial segment overlapping the area of repair The final steps in the procedure consists of resuturing the subscapularis tendon and reattaching the coracoid process with silk sutures

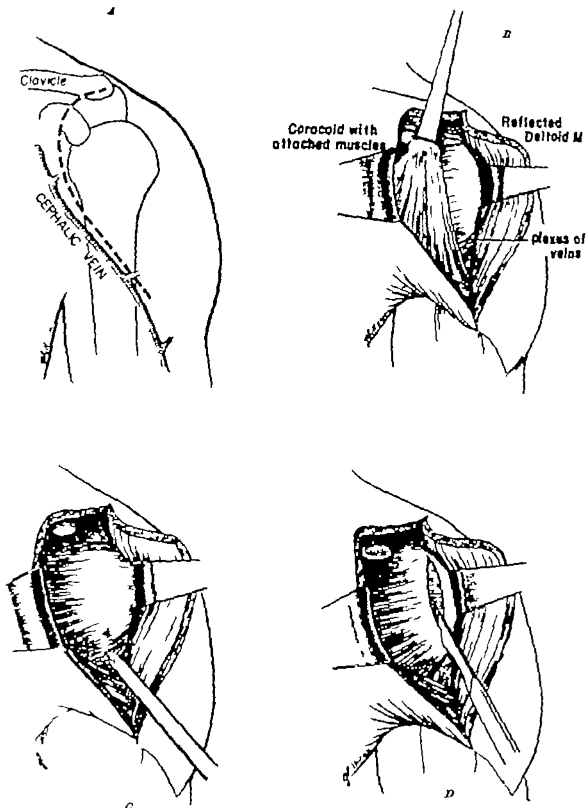


Fig. 243.—Bankart operation for recurrent dislocation of shoulder (technic Cave and Rowe). *A* Skin incision. *B* Osteotomy of coracoid process. *C* Muscles to coracoid reflected medially—blunt instrument identifies lower border of subscapularis muscle. *D* Dissection of subscapularis from lesser tuberosity and capsule. (From Cave, E. F., and Rowe, C. R. S. Clin. North America 27 1289 1947.)

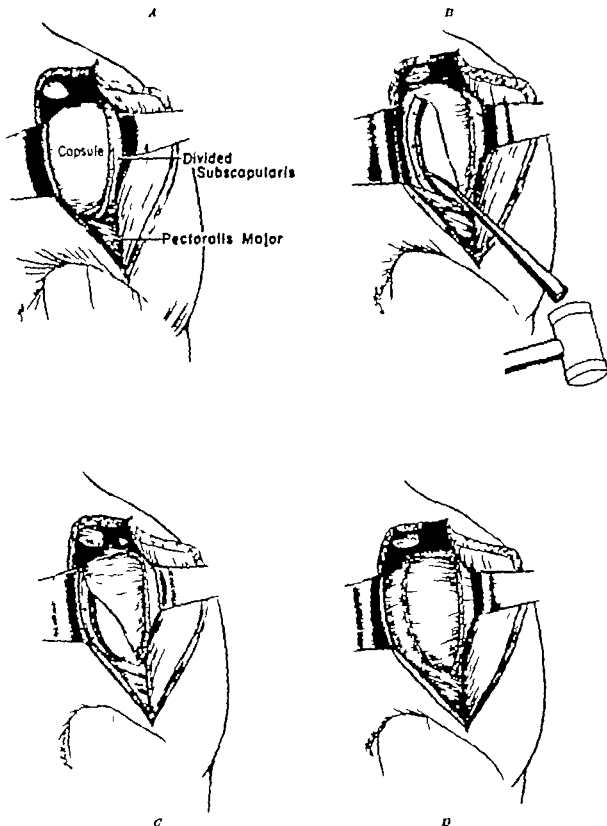


Fig. 244.—Same as Fig. 243 Bankart operation continued. *A*, Subscapularis reflected medially. *B*, Holes through rim of glenoid. *C* Securing lateral capsular flap with heavy silk suture. *D* Plication of proximal flap over lateral capsular flap. (From Cave E. F., and Rowe C. R. S. Clin. North America 27 1289 1947.)

After Treatment—The shoulder is immobilized by a Velpeau dressing for a period of ten days to two weeks. The arm is supported for an additional two weeks with a sling. Motion is allowed to the horizontal plane in approximately six weeks. Eight weeks postoperatively motion should have been regained, with the possible exception of slight limitation in abduction and external rotation and this is desirable.

In patients with a defect in the labrum the Bankart operation is usually sufficient. If there is a substantial defect in the humeral head with or without a lesion of the labrum, a procedure which limits external rotation such as the *Putti Platt operation described by H. Osmond Clarke, may be necessary.* This procedure shortens the subscapularis tendon by overlapping it in conjunction with plication of the capsule thereby producing a rather substantial barrier to redislocation and in most cases, *a permanent limitation of external rotation of* the shoulder.

Putti Platt Technic (H. Osmond-Clarke)—Exposure of the shoulder joint is obtained essentially by the same procedure as described above for the Bankart procedure. The subscapularis tendon is divided one inch medial to its insertion. In this process, frequently the capsule which is adherent to the deep surface of the tendon is opened. Having examined the joint for the common pathology *(Osmond Clarke notes this as being a tear of greater or* lesser degree in the gleno-labrial attachment, a defect in the head of the humerus and an extensive stretching and enlargement of the anterior capsule), the lateral edge of the subscapularis tendon is sutured to the soft tissue, sometimes the labrum itself, along the anterior rim of the glenoid cavity or as an alternative, to the deep surface of the stripped capsule and subscapularis muscle. Under these latter circumstances, the anterior surface of the neck of the scapula is scarified, thereby providing a stout attachment for the sutured tendo-capsule. The sutures are tied with the shoulder in internal rotation. Subsequently the medial portion of the capsule is sutured over the lateral segment of the subscapularis *tendon, finally the medial portion of the subscapularis is attached* to the tendinous cuff over the greater tuberosity, or to the bicipital groove, thereby overlapping all of the previous plications. After the procedure is complete, the structures should be sufficiently taut to limit external rotation of the shoulder at the neutral position. (Osmond Clarke cautions against excessive shortening of the subscapularis, thereby a stubborn internal rotation contracture may persist for some time after the operation.) Final steps in the procedure consists of resuturing the conjoined tendon to the coracoid process, the deltoid to the clavicle and pectoralis major and closure of the wound.

After Treatment.—With a Velpeau dressing the upper extremity is bandaged *to the trunk* with the *forearm* across the chest. This position of internal rotation is maintained for three or four weeks. Subsequently muscle power and motion are redeveloped, a rather rigorous regime ... ng instituted six weeks postoperatively.

Technic (Henderson)—A curved incisi... upward is made from just in front of the head of the humerus to t... aspect of the shoulder. The flap is refle... ard exposing the ... cle and th... romio-clavicular joint ... *10 mm in diamet...* throu... omion process. The fl... deltoid muscle ... ante... l pos-

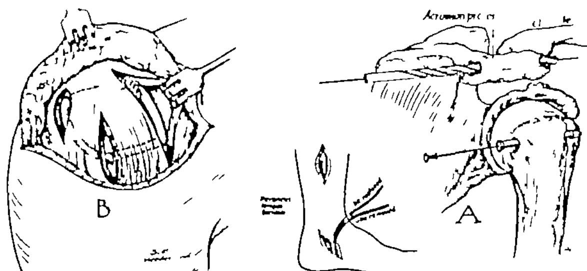


Fig. 243.—Henderson operation for recurrent dislocation of shoulder. *A*, Kirschner wire through acromion process used as a guide for cannulated drill. Trocar and cannula in hole through humerus facilitate passage of tendon through prepared channel. One-half of peroneus longus tendon used for suspensory ligament. *B*, Operation completed.

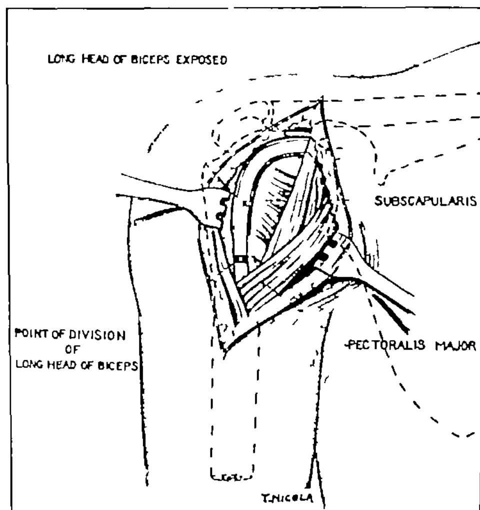
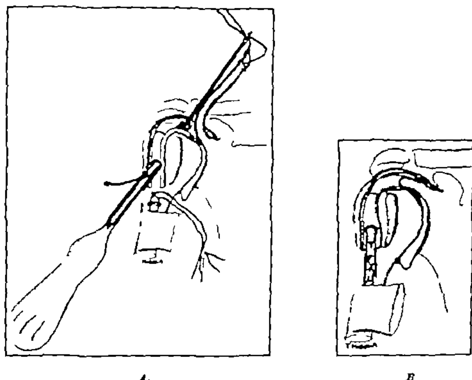


Fig. 244.—Nicola operation for recurrent dislocation of shoulder. Exposure of shoulder joint and long head of biceps. (From Nicola, T.: J. Bone & Joint Surg. 16: 663, 1934.)

teriorly the tendinous insertions of the supraspinatus and infraspinatus muscles are detached, and the capsule of the shoulder exposed The drill is then passed through the greater tuberosity of the humerus. A section of the tendon of the peroneus longus muscle, ten inches in length and consisting of one-half of the thickness of the tendon, is removed from the leg on the same side. This segment is passed through the drill holes, drawn taut, and its ends are sutured together with silk.

After Treatment.—The arm is strapped securely to the patient's side and so *maintained for ten days. Physical therapy is then instituted*



A. B

Fig. 247.—Same as Fig. 246. *A* Proximal end of long head of biceps passed distally through a channel extending from articular surface of head of humerus to bicipital groove. *B* Cut ends of long head of biceps united. Transverse humeral ligament is sutured to biceps at bicipital groove. (From Nicola, T J Bone & Joint Surg. 16: 663 1934.)

Technic (Nicola).—The incision is begun on the clavicle above the coracoid process and is carried down along the anterior border of the deltoid muscle a distance of four inches. The upper and anterior fibers of the deltoid are divided at their attachment to the clavicle, and the muscle is retracted outward. The pectoralis major muscle and the cephalic vein are retracted inward. The tendon of the long head of the biceps is exposed by division of the transverse humeral ligament which holds the tendon in the bicipital groove and by incision of the joint capsule in the line of the muscle fibers. Two stay sutures of black silk are placed in the biceps tendon one fourth inch apart and one inch below the cut margin of the transverse humeral ligament, and the tendon is divided between. If a suture is not placed in the distal end of the tendon before its division, a long unnecessary incision and considerable dissection may be required before this portion of the tendon can be recovered The synovial sheath of the proximal portion of the tendon is removed. A hole one fourth inch in diameter is drilled through the head of the humerus from just below the transverse ligament to the center of the articular surface of the

head of the humerus A Macey tendon carrier probe or wire loop is passed through the tunnel from below upward and the silk suture in the proximal portion of the tendon is drawn through the tunnel pulling the tendon thereafter The bicipital groove is scarified and the distal and proximal ends of the tendon united With the arm abducted to a right angle the tendon is sutured to the transverse humeral ligament

When the biceps tendon is very small or appears to be inadequate, and the patient is the muscular athletic type of individual the tendon may be reinforced with a one half inch strip of the coracohumeral ligament The latter is passed through the hole in the head of the humerus with the biceps tendon

After Treatment.—The shoulder is immobilized in a Velpeau dressing for a period of two or three weeks. Physical therapy although not essential will hasten convalescence

Roberts and von Baeyer s technics are similar in principle to that of Nicola The long head of the biceps is freed and the bicipital groove deepened and extended upward and inward across the articular surface of the head of the humerus when transplanted into this groove the tendon should sink below the level of the articular cartilage This procedure is perhaps less desirable than the Nicola operation in that a considerable portion of the articular surface of the head is destroyed leading to the possibility of a subsequent traumatic arthritis.

Posterior Recurrent Dislocation of the Shoulder

Posterior dislocation of the shoulder is a relatively uncommon lesion The diagnosis should be verified by lateral roentgenograms before surgery is undertaken

May reports three cases of habitual posterior dislocation of the shoulder wherein the Nicola operation was performed In two of these the outcome was successful. In the third recurrence necessitated a second operation apparently the biceps tendon had stretched though it had not been torn in two The second procedure was carried out by a technic similar to that described by Henderson. The dislocation had not recurred after several months

The Bankart operation has also been employed for posterior dislocations of the shoulder joint The pathologic findings and the technic of repair of posterior dislocations are essentially the same as those of the anterior dislocation. The exposure of the posterior aspect of the shoulder is described on p 159

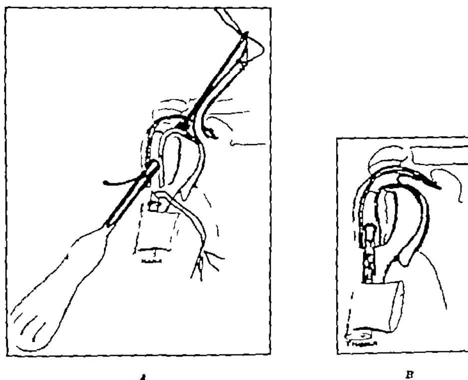
Recurrent Dislocation of Elbow

In recurrent dislocation of the elbow an exceedingly rare lesion the roentgenogram shows an excessively shallow semilunar notch. Milch describes a technic *which he employed in a case wherein the ulna was repeatedly dis*located beginning at fourteen months of age. The operation was designed to increase the convexity as well as the length of the semilunar notch

Technic (Milch).—A four inch incision was made on the anteromedial aspect of the elbow joint, following the course of the brachial artery After tying the median cephalic vein and incising the lacertus fibrosus, the biceps tendon was exposed and retracted laterally together with the brachial artery

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After Treatment.—The arm is strapped securely to the patient's side and so maintained for ten days. Physical therapy is then instituted.



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and vein The median nerve was then identified and retracted medially Division of the brachialis anticus in the line of its fibers, and a similar incision through the capsule, exposed the blunt tip of the coronoid process. *A hole one fourth inch in diameter was then drilled in the ulna, beginning at the tip of the* coronoid and extending obliquely backward and downward into the body of the ulna A bone graft shaped like a boomerang and about one and one-half inches long was removed from the anterior ridge of the tibia and placed in the previously prepared hole in the ulna so that the graft curved upward, continuing the contour of the semilunar notch. Following insertion of the graft the elbow could still be completely flexed

After Treatment.—The elbow was immobilized in flexion for a period of two weeks The immobilization was removed and the arm was allowed to straighten out by gravity There was no evidence of recurrence five months after operation

Gosman reports a similar case of dislocation in a girl fifteen years of age. The surgical procedure was essentially the same as that outlined by Milch although an ordinary rectangular peg was used because of its simplicity In the course of time, the natural absorptive processes rounded off this bony process. In Gosman s case the semilunar notch of the ulna appeared relatively normal the dislocation recurred apparently because of a congenital laxity of the soft tissues on the anterior surface of the elbow joint.

Reichenheim successfully treated his case (a soldier aged 25 years) by transplanting the tendon of the biceps into the coranoid of the ulna. The elbow was exposed by a Henry approach, and the brachialis muscle split to expose the coronoid process of the ulna The biceps tendon was then detached and reinserted in the ulna with two wire sutures. The split in the brachialis was closed in front of the biceps tendon

Recurrent Dislocation of Carpometacarpal Joint of the Thumb

For chronic dislocation of the carpometacarpal joint of the thumb Slocum creates a so-called ligamentum teres utilizing Nicola's principle in operations on the shoulder In addition he reinforces the posterior capsule of the joint.

Technic (Slocum) —An incision one and one half inches in length is made parallel to the extensor pollicis longus tendon at the distal end of the anatomic snuffbox, exposing the base of the first metacarpal bone and the greater multangular bone From a point approximately one-half inch distal to the joint, a hole is drilled obliquely downward through the metacarpal bone to the center of the articulation to coincide with a similar hole drilled from the dorsal lateral aspect of the greater multangular to the center of its articular surface. Through a separate incision, a section of the palmaris longus tendon is removed. This tendon is then threaded through the holes in the two bones and while the thumb is held in moderate opposition, is sutured on itself to form a loop The ends of the tendon are plicated backward and forward across the joint to reinforce the posterior capsular ligament.

After Treatment.—A cast is applied, holding the thumb in the neutral position At the end of three weeks, the cast is removed and physical therapy and exercises begun.

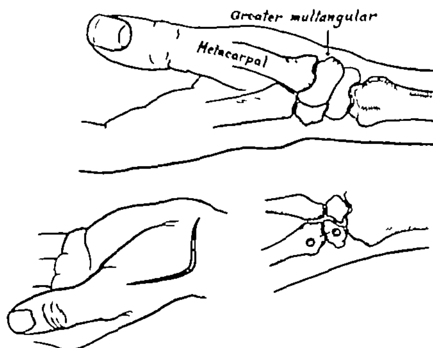


Fig. 718.—Slocum procedure for recurrent dislocation of carpometacarpal joint of thumb. Section of palmaris longus tendon is threaded through tunnels in greater multangular and base of metacarpal bone, and sutured to itself to form a loop ends are plicated across back of joint to reinforce posterior capsular ligament.

Recurrent Dislocation of the Metacarpophalangeal Joint of the Thumb

Recurrent dislocations of this joint are exceedingly rare. Milch reported one case wherein a dorsal dislocation occurred repeatedly upon hyperextension of the thumb Although the luxation was easily reduced, considerable disability resulted, as the patient was a manual laborer Open reduction was carried out by the following technic.

Technic (Milch).—After exposure of the joint the capsule is opened by a cruciform incision plicated in two directions, then further reefed and narrowed by a purse-string suture passed around the entire incision The lower edge of the first dorsal interosseous muscle is sutured to the metacarpal bone just above the metacarpophalangeal articulation.

After Treatment.—A small molded plaster splint is applied to prevent excessive extension of the thumb At the end of two weeks, physical therapy and gentle active motion are begun. Use of the thumb is gradually resumed after three weeks.

UNREDUCED DISLOCATIONS

Failure to reduce a dislocation immediately after injury leads rapidly to disaster The articular cartilage when no longer bathed in synovial fluid and partially or completely deprived of circulation, degenerates after a few weeks and often becomes detached from the bone. As a consequence pain and limitation of motion may persist even after open reduction. In the hip elbow and ankle particularly the question often arises as to whether an arthroplasty or a fusion of the joint may not be advisable at the time of operation for an old unreduced dislocation This depends upon the condition of the articular surface and to some extent upon the social status of the patient

Old unreduced dislocations can be replaced only by open operation. There is no arbitrary time when a dislocation may be regarded as irreducible by closed measures. With the newer methods of skeletal traction closed reduction often may be accomplished much later than formerly and when apparently possible, should be given a trial

After the lapse of three weeks, and in some cases less, manual reduction should be undertaken with caution and excessive force avoided because of the danger of fracture of one or more of the bones. Nor should undue force be *exerted during the course of an operation for reduction* Osteoporosis and bone atrophy begin early and progress rapidly and the bone may be so soft that even the slight pressure of an instrument used for leverage may cause permanent damage by grossly compressing the articular surfaces. Before reduction is attempted the joint should be widely exposed and the soft tissues elevated subperiosteally until the bony structures are freed

The prospect of securing good function diminishes with the lapse of time. The age of the patient also has a bearing upon the ultimate result In all young adults, the procedure is well justified as material improvement in function can be assured but the prognosis is less favorable in middle aged or elderly individuals. In some cases, reduction is impossible or may necessitate so much surgery or force as to be unsafe.

Although an unreduced dislocation is possible in any joint only those *more frequently encountered will be discussed*

Open Reduction of Old Unreduced Fracture-Dislocation of the Ankle

Unreduced dislocations of the ankle uncomplicated by fractures are extremely rare Practically always, the type and degree of dislocation of the ankle are dependent upon an associated fracture anterior dislocations are complicated by fractures of the anterior margin of the articular surface of the tibia, posterior dislocations by fractures of the posterior lip and a portion of the shaft of the tibia or Cotton's fracture and lateral displacements by *bimalleolar fractures of the tibia and fibula. A full discussion of this subject* therefore is found in the chapter on Malunited Fractures.

Following a dislocation of long duration, whether or not associated with a fracture traumatic arthritis, with pain and disability may persist even after reduction. For this reason, fusion of the ankle after reduction will often permit far better function nevertheless, the majority of patients, rather than forego the possibility of obtaining motion, prefer to take the risk of a painful joint with the option of fusion later

Open Reduction of Old Unreduced Dislocation of the Knee

A functional degree of motion is seldom restored after open reduction of old dislocations of the knee. Even though the cartilage may apparently be in normal condition, exfoliation and adhesions of the articular surfaces usually follow If reduction cannot be accomplished without extensive dissection and sacrifice of important structures, an arthroplasty (Ch XVII) or arthrodesis (Ch XV) of the knee is the procedure of choice. If the patient is a young adult, arthroplasty is preferable, in an elderly person, fusion will give a better result

Technic.—The joint may be approached through the anteromedial incision (p 140) If the patella is displaced to either side, the incision should be made to correspond to the normal situation of the internal border of the quadriceps tendon If necessary, the soft structures, together with the periosteum may be dissected from the posterior aspect of the femur and tibia All fibrous tissue is excised and the articular surfaces exposed If the cartilage is un impaired reduction may be effected by the technic described for fresh dislocations of the knee

After Treatment—(See p 291)

Open Reduction of Old Unreduced Dislocation of the Patella

Unreduced dislocations of the patella occasionally are compatible with satisfactory function of the knee In neglected cases, there may be a valgus deformity of the knee with lateral rotation of the tibia on the femur A traumatic arthritis develops, motion is limited and pain and disability persist. In young adults, if the contour of the joint can be restored an arthroplasty is preferable In those above thirty five or forty years of age, or those who are engaged in laborious occupations, osseous fusion will afford a more useful member

When the tibiofemoral articulation is relatively normal in contour and alignment, the following procedure may be employed even so the prognosis as to adequate function is doubtful

Technic.—A three inch longitudinal incision is made in the midline The lateral border of the incision is dissected subcutaneously and the capsule and synovium opened parallel with the lateral border of the quadriceps tendon and patella. The quadriceps tendon and patella are dissected free and replaced in normal position. The redundant internal capsule may be excised and the opening in the capsule closed or the flap may be transferred from the inner to the outer side of the knee A transference of the tibial tubercle to realign the quadriceps mechanism (Hauser operation) must supplement the above procedure. If the patella has undergone degenerative changes, a patellectomy will be necessary

After Treatment.—(See p 314.)

Open Reduction of Old Unreduced Dislocation of the Hip

If dislocation of the hip is not reduced within three weeks, and in some cases earlier skeletal traction or open reduction will be imperative The acetabulum will have become rapidly filled with fibrous tissue and fat, the rent in the capsule closed with scar tissue, and the head of the femur adherent to the surrounding structures atrophic changes will have taken place in the osseous structures of the head and neck of the femur When these changes are present manual reduction is impossible and if attempted, may further complicate the situation by causing fracture of the head or neck of the femur or excessive fibrosis from trauma and tearing of the soft tissues.

As dorsal dislocations are of more frequent occurrence the technic of their reduction alone will be described in detail

In dislocations of three to eight weeks duration a Kirschner wire may be inserted through the condyles of the femur and twenty to thirty five pounds

of skeletal traction applied to the extremity This may stretch the contracted structures sufficiently to allow the head to descend partially or completely to the acetabulum and thus facilitate or obviate the operative procedure.

In young adults or children with a dislocation of long duration, a two-stage procedure may be advisable. At the first stage the head and neck of the femur are freed and fibrous tissue is removed from the acetabulum, as described below If reduction cannot be effected without considerable trauma to the head of the femur and extensive dissection of the soft tissues, the wound is closed and skeletal traction instituted. Roentgenograms are made at frequent intervals to determine the position of the head. When the head is opposite the acetabulum, the extremity is abducted and reduction attempted, if the attempt is unsuccessful, open reduction is carried out

Technic.—The joint is approached through the anterior iliofemoral incision (p 146), the attachments of the gluteal muscles being stripped from the anterior two thirds of the ilium. The head of the femur is located on the dorsum of the ilium and dissected free from scar tissue or fibrotic muscles, which may completely encircle the head and neck. Soft tissue attachments to the femur and the Y ligament are conserved as much as possible. After incision of the capsule the acetabulum is cleared of all fibrous tissue, then, with the hip flexed to a right angle and adducted an attempt is made to reduce the head into the acetabulum by means of a bone skid while traction is exerted in line with the thigh by an assistant. In dislocations of relatively short duration reduction may be complete.

If the dislocation has been present for several years, even though the articular cartilage is apparently well preserved, open reduction alone is not sufficient The soft tissues will be so severely contracted that only by extensive dissection of the attachments to the head and neck, and even to the lesser and greater trochanters, can the head be reduced into the acetabulum Such a procedure leads to impairment of circulation and subsequent degenerative changes. Instead, the head of the femur may be trimmed to a smaller size and the acetabulum enlarged proximally with a chisel. The head of the femur may even then be under such tension that a pressure necrosis will ensue. The degenerative and proliferative changes may become so extensive that motion will be limited and painful In young individuals, a complete arthroplasty may be advisable, and in the middle aged the joint should be fused provided arthritic changes in the spine are not excessive.

After Treatment.—Strips of adhesive tape are applied on each side of the thigh, and the leg is well padded with several layers of flannel bandage With the joint extended, abducted 170 degrees, and in a position midway between internal and external rotation, the hip is immobilized in a plaster cast extending from the ankle to the nipple line. Buck's extension is applied with ten pounds of traction After three weeks the cast is bivalved and active and passive exercises of the hip are instituted between exercise periods, the patient should lie in the back half of the cast while traction is continued. Six weeks postoperatively a Thomas caliper brace is fitted and weight bearing allowed The brace is worn for six months, or until function is well established and the structure of the bone approaches normal.

The end result of procedures wherein the head is replaced in the acetabulum and motion preserved is always doubtful until the lapse of at least one

year, as degenerative changes of the head may occur, necessitating an arthroplasty or arthrodesis for relief of symptoms.

An external rotation contracture of the hip is a common sequela of open reduction. To restore alignment and permit flexion of the knee in a normal plane, a supracondylar osteotomy is performed and the lower portion rotated internally.

After long continued dislocation, an accessory or compensatory socket occasionally is formed upon the dorsum of the ilium by functional adaptation. The patient walks with a peculiar limp as the new articulation is on a plane posterior to the acetabulum, the relations of the muscular attachments are altered and the actual length of the limb is decreased. In these cases, a Lorenz bifurcation operation or a Schanz osteotomy (Chapter XXV) might be most appropriate.

Open Reduction of Old Unreduced Dislocation of the Hip With Fracture of the Acetabulum

In the presence of an old dislocation of the hip with a fracture of the acetabulum, wherein the head of the femur is completely out of the acetabulum and displaced upward on the side of the wing of the ilium, the principles described above, for open reduction of old unreduced dislocations of the hip apply. If the head of the femur has remained in a relatively normal position, or is only slightly displaced, the treatment is similar to that of any traumatic arthritis of the hip, and the prospect of restoring a movable hip is good. The prospect of restoring motion decreases in proportion to the extent of disassociation of the acetabulum and head, and the displacement and comminution of the acetabulum. Obviously the longer treatment is delayed, the less promising the outcome.

Two alternatives as to treatment are available: arthroplasty or arthrodesis. If the head can be introduced into the acetabulum with minimal tension, a routine mold arthroplasty is performed. In some instances, the process may be facilitated by enlarging the acetabulum proximally. If the head of the femur is necrotic, the mold arthroplasty and Whitman reconstruction operation may be combined.

Arthrodesis is indicated in the presence of pronounced incongruity and distortion of the acetabulum, particularly if the head of the femur and acetabulum partially or completely protrude into the pelvis. If the patient engages in an occupation which requires considerable walking or standing or is a manual laborer, arthrodesis is the only means of providing a stable, painless, weight bearing member.

Open Reduction of Old Unreduced Dislocation of Temporomandibular Joint

Unreduced dislocations of the jaw are seldom encountered. The condition is so disabling and the diagnosis so apparent that reduction is usually effected at once. As the dislocation is practically always bilateral, the following procedure must be carried out on both sides.

Technic.—A skin incision is begun one half inch anterior to the external auditory meatus, extended forward along the zygomatic process for one and one half inches, thence upward one and one-half inches at a right angle to the

beginning of the first incision thus forming an L or reverse L. Dissection is carried down to the zygoma, and to the dislocated temporomandibular joint. The articular disk and all scar tissue are removed from the mandibular fossa. The condyle of the mandible is then located anterior to the articular tubercle and freed of adhesions. A similar procedure is then carried out on the opposite side. The incisions are covered while an assistant exerts backward and downward pressure upon the lower molars with the thumbs, and at the same time lifts the chin forward and upward with the fingers.

When the articular surfaces are beyond repair an arthroplasty (Ch. XVII) or excision of both condyles of the mandible should be carried out after reduction.

After Treatment.—Mobilization should be instituted immediately and continued at intervals of one or two hours until the patient can open the mouth to a normal degree. Restoration of motion may be cultivated by the insertion of wedges between the teeth and by physical therapy. Chewing gum is a convenient form of exercise.

Open Reduction of Old Unreduced Dislocation of the Shoulder

Open reduction of dislocations of the shoulder is indicated in practically all cases after the lapse of four to six weeks or when manual reduction is possible only by the use of excessive force. Undoubtedly manual reduction succeeds occasionally at a comparatively late date; osteoporosis develops so rapidly however that there is grave danger of fracture of the surgical neck of the humerus or damage to the joint surfaces.

Technic.—An incision is made on the anterior aspect of the shoulder extending from the outer third of the clavicle downward on the arm a distance of four or five inches. The deltoid and pectoralis major muscles are separated, and the short head of the biceps and the coracobrachialis muscles are retracted. The head of the humerus may then be observed or felt with a blunt instrument beneath the coracoid process. Reduction cannot be accomplished until the capsule is opened, the coracohumeral ligament completely severed and the glenoid fossa freed of fibrous tissue. To reduce the dislocation without undue force the attachments of the subscapularis and of the pectoralis major muscle must often be severed, and the upper extremity of the humerus freed of all fibrous adhesions. The head of the humerus may then be easily replaced within the glenoid. The soft tissues must be stretched to provide sufficient space for free motion of the head of the humerus. Repair of the capsule usually is impossible on account of its constricted state.

During operation force, both manual and instrumental, should be exerted reservedly as irreparable damage may be inflicted by compression of the soft, osteoporotic bone.

After Treatment.—The shoulder is immobilized in a humerus splint or cast preferably in the position of slight abduction and flexion and neutral rotation. At the end of ten days, if the wound has healed active and passive motion and physical therapy are instituted. The shoulder should be supported by the splint at night for several months, until a fair degree of strong active abduction is restored.

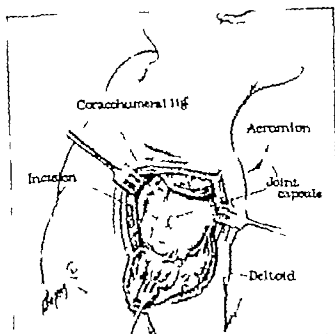


Fig 249 —Reduction of old or irreducible dislocation of shoulder Exposure by Cubbins incision. (From Cubbins et al Surg, Gynec., Obst. 58: 1 9 1934.)

Hole bored through acromion to receive transplant
Thick, fibrous attachment of deltoid
Glenoid cavity filled with adhesions
Coraco-humeral lig. separated for transplant
Long head of biceps
Head of humerus
Much thickened capsule
Deltoid

Fig. 250 —Same as Fig. 249 Capsule incised. Coracohumeral ligament dissected free. Biceps tendon in anterior position. (From Cubbins et al. Surg. Gynec. Obst. 58 129 1934.)

Full function rarely follows this procedure, motion being limited principally in abduction and external rotation. Further because of periarticular changes and arthritis, motion may be painful

Technic (Cubbins et al.)—The joint is exposed by a Cubbins incision (p 155), the capsule is incised along the course of the biceps tendon, and the latter is freed from the bicipital groove. The head may be returned to the glenoid by one of two methods In the first, the capsule and accompanying tendons from the greater tubercle are freed well down on the posterior surface of the humerus and the joint is denuded of fibrous tissue The head is then

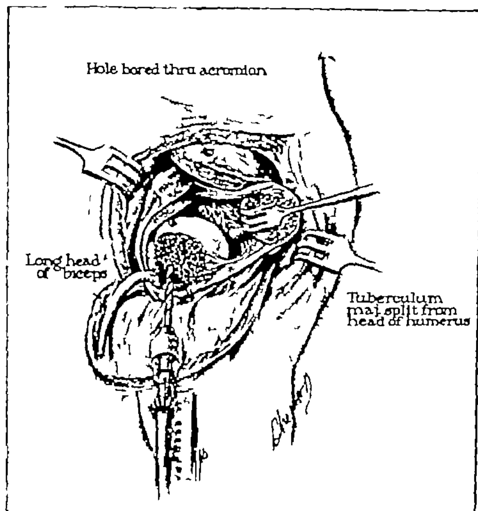


Fig 251.—Same as Fig. 249 Coracohumeral ligament passed through hole in acromion for fixation. Insert shows position of postoperative fixation. (From Cubbins et al Surg. Gynec. Obst 58 129 1934)

reduced and the capsule, with its tendons, sutured to the tuberosity with chromic catgut If the needle cannot be forced through the atrophic bone, one or two holes are drilled through the tuberosity for passage of the suture. In the second method, the greater tuberosity is removed with a chisel and the entire mass reflected. The capsule is incised transversely one-fourth inch from the greater tubercle and reduction is accomplished as described above For fixation the Nicola procedure (p 324) may be carried out, or the long head of the biceps may be fixed through a tunnel in the acromion process, or a slip of

the coraco humeral ligament may be passed upward through the hole in the acromion and utilized as a suspensory ligament

After Treatment.—The arm is dressed in the position of salute and so maintained for four to six weeks by means of a cast. The cast is carefully removed at this time and utilized as a convalescent splint until active and passive motion are adequate to warrant removal of support.

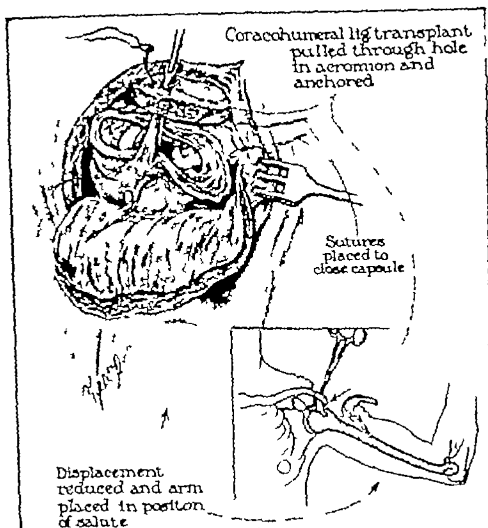


Fig. 212.—Same as Fig. 211 Alternate method of internal fixation. Greater tubercle removed and reflected posteriorly with capsule to expose joint cavity Long head of biceps passed upward through drill holes and attached to acromion. (From Cubbins et al. Surg Gynec. Obst. 58: 129, 1934.)

Open Reduction of Old Unreduced Fracture-Dislocation of the Shoulder

The disability incident to fracture-dislocations of the shoulder is so extreme as to warrant surgical intervention, regardless of the duration of the injury Treatment, however becomes increasingly difficult with the passage of time If the patient is elderly or if the fracture dislocation is of many years duration with extensive degenerative changes of the articular surfaces, the head of the bone is excised and the shaft of the humerus replaced within the glenoid, *according to Jones* tenoplastic procedure (p 472)

In young patients the head of the humerus should be reduced and the fragments placed in proper apposition and alignment The end results of this operation are proportionate to the duration of the fracture-dislocation Even in rela

tively early cases, there may be considerable residual pain and limitation of abduction and external rotation If pain and disability persist to an extreme degree one always has recourse to fusion

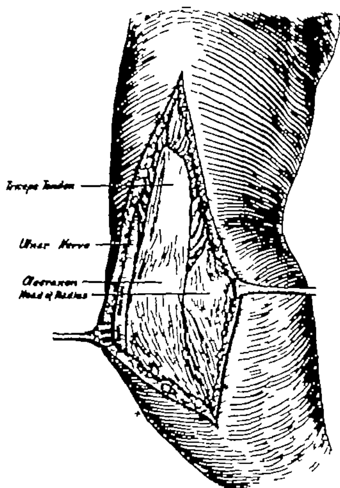


Fig 253.—Operation for unreduced posterior dislocation of elbow (Campbell) Exposure of triceps aponeurosis and isolation of ulnar nerve.

Open Reduction of Old Unreduced Dislocation of the Elbow

As unreduced dislocations of the elbow are usually posterior the treatment of this type alone will be described. Old dislocations of other types may be reduced by technics similar in principle

The dislocation may be regarded as irreducible within three weeks following trauma. Adhesions are then formed which materially restrict function the elbow may be held in a position of complete extension or in approximately 160 degrees flexion. After the lapse of months, a new joint with a few degrees of motion may be formed by functional adaptation. A serviceable joint however is not possible the semilunar notch and the olecranon fossa become filled with dense fibrous tissue the displaced joint capsule adheres to the articular surfaces, adhesions form about the lower extremity of the humerus, the upper end of the ulna, and the head of the radius, and the muscles and bones become atrophic Masses of callus may unite the ulna to the humerus or the radius to the humerus, or may fuse the entire articulation

Technic (Campbell).—An incision is made over the posterolateral aspect of the arm beginning in the midline four inches above the olecranon process and ex

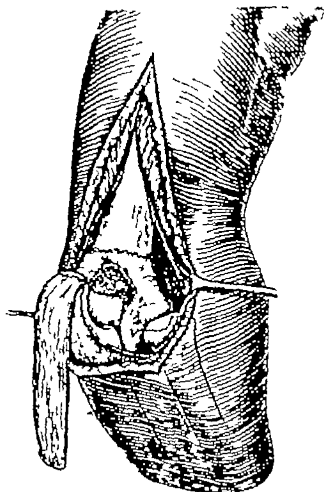


Fig. 244.—Triceps tendon dissected free and reflected distally. Incision through muscle fibers to humerus. Muscles stripped subperiosteally from shaft and both *condyles* of humerus, completely mobilizing this part of bone.

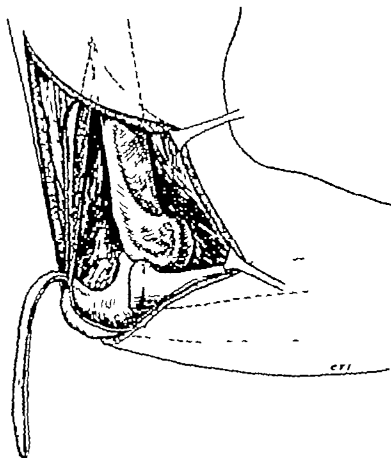


Fig. 245.—Lateral view shows extreme limits of mobilization occasionally necessary for reduction.

tending down to just above the tip of the olecranon, thence slightly outward over the external condyle of the humerus, the head of the radius, and continuing two inches on the forearm. The edges of the incision are elevated and retracted, exposing the tendinous insertion of the triceps muscle and the posterior surface of the elbow joint.

The tendinous aponeurosis of the triceps muscle is dissected out at its proximal end and turned downward as a tonguelike flap, remaining attached to the olecranon. An incision is next made directly in the midline through the fibers of the triceps muscle down to the humerus, extending from three inches upon the shaft to the reflection of the joint capsule around the articular surfaces.

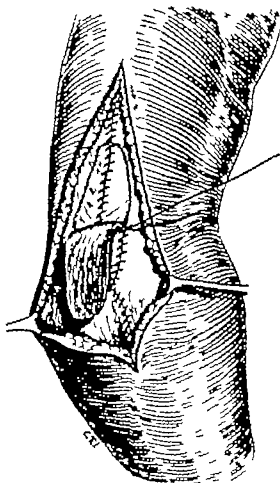


Fig. 236.—Fibers of triceps muscle sutured. Aponeurosis of triceps being sutured.

All the muscular attachments over the lower end of the humerus, both anteriorly and posteriorly, are stripped free, together with the periosteum. The *attachments of the joint capsule around the condyles of the* humerus are then separated close to the bone. If dissection is carried close to the bone the ulnar nerve rarely comes into view, but may be located and detached from its bed along the groove in the internal condyle and retracted out of danger. Often there is considerable callus formation over the posterior surface of the humerus around the olecranon fossa, from stripping up of the periosteum *at the time of* the original injury; this callus with the scar tissue in the olecranon fossa is thoroughly removed.

Having completely freed the lower end of the humerus and exposed the capitellum and head of the radius, the forearm is twisted with gentle pressure

over the capitellum causing the head of the radius to glide forward into the normal position. If this is not readily accomplished, the soft tissues should be dissected more widely to obviate the necessity for the use of force and consequent danger of injury to the articular surfaces. After the radius is reduced, the coronoid process may be slipped forward over the trochlea and reduction completed The joint is then carried through the full range of motion The periosteum and muscles are closed along the posterior surface of the humerus, and the fascia is sutured over the head of the radius. The aponeurosis of the triceps muscle is sutured into its normal position or at a slightly lower level.

After Treatment.—The arm is immobilized in a right angle posterior splint for seven to ten days, depending upon the amount of operative reaction The splint is fitted with straps and buckles, and the arm is removed several times a day for the practice of gentle active and passive motion and physical therapy When a fair range of strong active motion has been re-established the splint may be discarded during the day but should be worn at night for an additional two to three months, to prevent contractures. If the dislocation has been present for a long time the best functional result can be obtained only by continuing the after treatment indefinitely Children, of course, respond more quickly than adults.

The prognosis is in direct proportion to the time which has intervened between the fresh dislocation and the operation. In children with dislocations of long standing open reduction should always be carried out, as a more normal contour is formed for future reconstruction, even though motion is not secured In adults with old dislocation an arthroplasty is preferable at the time of reduction since satisfactory function can rarely be restored after a lapse of eight weeks.

Open Reduction of Malunited Fractures of the Ulna With Old Unreduced Dislocation of the Head of the Radius (Monteggia Fracture)

See chapter on Malunited Fractures (p 571)

Open Reduction of Old Unreduced Posterior Radiocarpal Dislocation

For dislocation of only three to four weeks' duration, open reduction may be undertaken provided the cartilaginous surfaces are well preserved

Technic.—A three-inch longitudinal incision is made over the dorsum of the wrist between the extensor indicis proprius and the extensor pollicis longus tendons. All scar tissue is removed exposing the carpal bones and lower extremity of the radius and ulna A periosteal elevator is then inserted between the carpus and radius and the bones pried into normal relationship

After Treatment.—The wrist is placed in dorsiflexion and immobilized in a cock up splint for ten days. At that time passive and active motion are begun and practiced at regular intervals, the splint being retained until active dorsiflexion of at least 150 degrees is possible

Anterior dislocations may be treated in the same manner through an anterior incision (p 169) In approaching the joint the median nerve should be isolated and retracted

If the dislocation has been present for several months the soft tissues will have become so contracted that excessive stripping will be necessary before

reduction can be effected further the articular surfaces will have so degenerated that adequate function will not be possible following open reduction. In this event, excision of the scaphoid semilunar and triquetrum may restore 50 per cent or more of normal motion. If the articular surfaces of the wrist are seriously affected however a complete arthroplasty (Chapter XVII) or arthrodesis (Chapter XV) is the procedure of choice

Unreduced Dislocation of Os Magnum With or Without Fracture of the Scaphoid Bone

Neglected cases of this type are usually occasioned by a misinterpretation of the original roentgenograms In relatively recent injuries an attempt may be made to secure reduction by the methods described for a fresh injury of this type (p 307) Cave notes that if this form of therapy fails, there are two alternatives (1) excision of the semilunar and scaphoid bone, (2) arthrodesis of the wrist. In most instances the latter procedure will be preferable.

Open Reduction or Excision of Old Unreduced Anterior Dislocation of the Semilunar Bone

In dislocation of several weeks' duration, open reduction of the semilunar bone is feasible but may be followed by Kienböck s disease Excision is regarded by some authors as more suitable than reduction and when there is some question as to whether excision or reduction is advisable, should be *given preference Excision may be accomplished with little difficulty through* the anterior approach described below

Technic.—An incision three inches in length is made over the anterior aspect of the wrist exposing the palmaris longus tendon and the median nerve. *Dissection is carried down lateral to these structures between the flexor sub*limis and profundus digitorum tendons. The semilunar bone usually is found just distal to the pronator quadratus muscle Fibrous tissue between the scaphoid and cuneiform bones should be removed and all adhesions detached *from the semilunar bone With a small skid the bone is slipped into this space* as the hand is brought from extreme extension to extreme flexion or the bone may be removed

After Treatment.—Following open reduction, the wrist is maintained in *acute flexion to prevent recurrence of the dislocation If the semilunar* bone has been excised the wrist is immobilized in dorsiflexion In either event, passive and active exercises are begun at the end of fourteen days. Motion must be instituted cautiously after open reduction The splint is discarded *when a fair degree of dorsiflexion is restored*

Open Reduction of Old Unreduced Carpometacarpal Dislocation

Shorbe states that old dislocations of these joints are serious problems *and reduction should be attempted* only after due consideration Only the appearance of the hand is improved. Function usually is satisfactory prior to operation and may even be diminished subsequently

One or all of the carpometacarpal joints may be dislocated that of the *thumb* being most subject to injury and most disabling The displacement as a rule, is posterior (See Recurrent Dislocation p 326 and Malunited Bennett s Fracture, p 599)

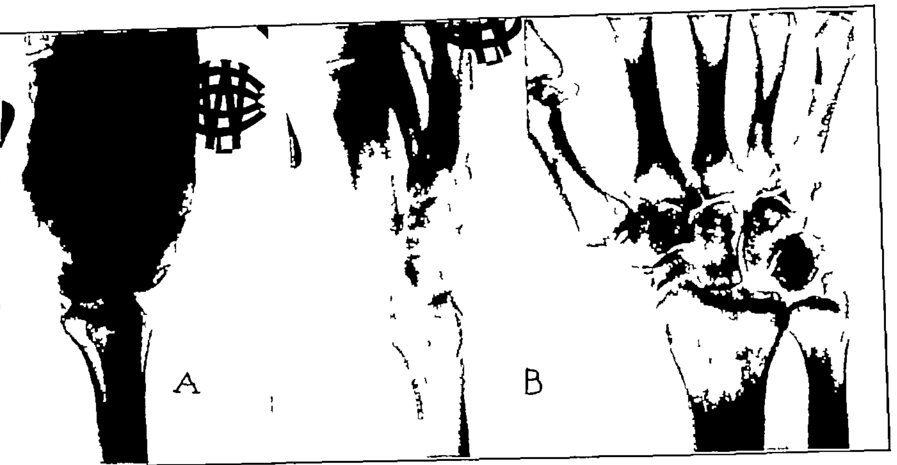


Fig 257.—A Old posterior dislocation of carpus with semilunar bone in normal position. B Satisfactorily functioning wrist after open reduction and resection of semilunar bone and portion of scaphoid.

Technic.—A longitudinal incision is made over the dorsal prominence of the dislocated metacarpal bone the extensor tendons are retracted, and the scar tissue is excised from around the base of the bone If the dislocation is



Fig. 218.—*A* Old anterior dislocation of semilunar bone. *B* After removal of semilunar bone.

of relatively short duration, the bone may be levered back into position by a periosteal elevator If reduction cannot be accomplished, a sufficient amount of the *bases of the metacarpal and carpal bones* is excised to allow reduction In the

event the reduction is unstable the joint surfaces are fixed by the insertion of a small Kirschner wire through the carpus across the joint surface and into the base of the metacarpal bone, engaging the anterior cortex. The end of the wire should be allowed to extend subcutaneously to facilitate its removal after four to six weeks.

After Treatment.—The hand is immobilized on an anterior plaster molded splint extending from just proximal to the metacarpal head to well up on the forearm The wrist is held in a neutral position Four weeks of immobilization is usually adequate

Since changes in the articular cartilage are so extensive that restoration of normal and painless motion is impossible, the joint is allowed to fuse. Satisfactory compensatory motion is usually obtained in the other joints

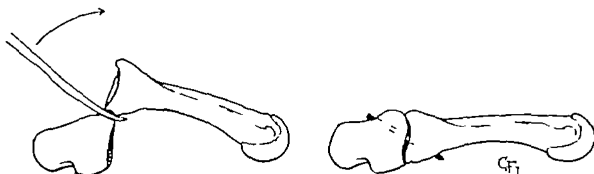


Fig. 230.—Open reduction of carpometacarpal dislocation. Fixation maintained by interosseous pin passed across joint.

RELAXED DISLOCATIONS

This term describes a type of dislocation which is easily reduced but cannot ordinarily be maintained satisfactorily by external fixation The joints in which this condition occurs are distal and proximal tibiofibular sternoclavicular acromioclavicular and proximal and distal radio-ulnar The normal anatomy permits a constant state of dislocation or subluxation if the ligaments are stretched or torn

Dislocation of the Distal Tibiofibular Joint

Dislocation of the distal tibiofibular joint usually is accompanied by a fracture of the internal malleolus. Occasionally however a complete separation of the distal tibiofibular joint is associated with a rupture of the deltoid or internal lateral ligament of the ankle joint. In the majority of cases, conservative treatment is adequate If on the contrary check up roentgenograms at the end of a week or ten days still show separation of the two bones, operative interference is justified otherwise the ankle joint will be unstable and a traumatic arthritis will ensue from widening of the ankle mortise

Technic.—A two-inch incision is made parallel to the anterior border of the lower end of the fibula through this incision, the distal tibiofibular joint may be exposed with a minimum of dissection The dislocation is reduced by pressure on the lateral aspect of the fibula No attempt is made to resuture or reattach the ligaments. With the joint in dorsiflexion and without disturbance of the tibiofibular articulation, a stainless steel screw is then



Fig. 260—*A* Unreduced dislocation of fourth carpometacarpal joint. *B* After reduction and fixation by screw

inserted transversely across the joint from the fibula into the tibia If the foot is held in equinus at this time the narrowest portion of the astragalus will be in the ankle mortise thus, when the foot is later dorsiflexed, the wide portion of the astragalus will be wedged between the malleoli preventing complete dorsiflexion Roentgenograms should be made in the operating room to determine whether the normal ankle mortise has been restored and the screw is in proper position

After Treatment.—The foot is immobilized for a period of three weeks, a walking cast is then applied and worn for a period of four weeks. The stainless steel screw should be removed from the ankle at the end of eight weeks, since the screw is subcutaneous, this is a relatively simple procedure Normally, little motion is present in the tibiofibular joint If possible, this motion should be preserved in order to provide elasticity to the joint on abduction or external rotation strains of the ankle mortise If the patient should later develop a painful arthritis of the distal tibiofibular joint, one may resort to fusion

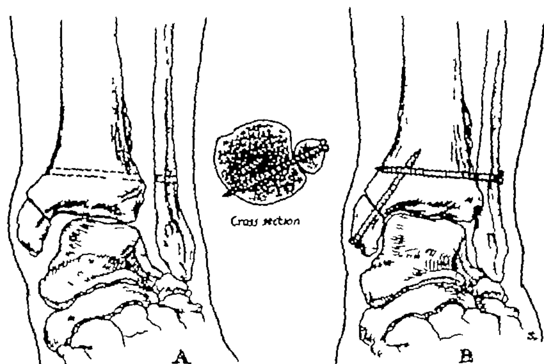


Fig. 281—*Dislocation of distal tibiofibular articulation with fracture of internal malleolus. B Internal malleolus and tibiofibular joint fixed in position by screws Cross section shows proper angles and relations of screws.*

Dislocation of the Proximal Tibiofibular Articulation

In old dislocations of this joint, function may be unimpaired. No treatment is indicated unless there is a strain upon the knee joint, pain and tenderness from frequent injury of the prominent head of the fibula, or symptoms of pressure on the peroneal nerve Treatment consists of open reduction and arthrodesis of the joint to maintain the normal position of the tibia and fibula.

Technic.—The superior tibiofibular articulation is exposed through a three inch longitudinal incision just medial to the head of the fibula. The peroneal nerve is isolated The articular surfaces are denuded and the head of the fibula forced into approximation with the denuded area on the tibia. Internal fixation is seldom necessary, as the head generally remains in close

apposition with the tibia. If this position cannot be satisfactorily maintained however, a rustless steel nail or screw may be inserted.

After Treatment.—(See p 291)

Dislocation of the Sternoclavicular Joint

With ordinary usage, dislocation of the sternoclavicular joint is not particularly disabling The proximal end of the clavicle frequently is displaced downward and forward overlapping the first rib to some extent, and becomes relatively well fixed in this position. If however the end of the clavicle is sufficiently unstable to luxate in and out of its position with movements of the shoulder girdle, reconstruction procedures may be advisable This is particularly true for patients in certain occupations and for athletes. The latter are disabled especially on throwing motions.

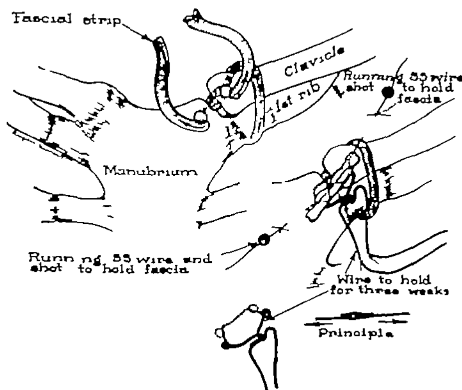


Fig 62.—Bunnell operation for dislocation of sternoclavicular joint. Fascial repair is reinforced by a kinked, removable stainless steel wire fastened outside the skin with two shot. After healing of fascia is complete (three weeks) kink is released by pulling on each end, and wire is removed. (From Bunnell, S. Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.)

In 1924 Allen described a repair of the sternoclavicular articulation *wherein stabilization was accomplished by means of a fascial loop* The fascia was passed vertically through a hole drilled in the proximal end of the clavicle, thence through a hole drilled in the second rib The J S Speed technic, described below is a modification of the Allen operation.

Lowman and Bankart have also developed methods of repair of sternoclavicular dislocation The Lowman procedure embodies the creation of a ligamentum teres across the sternoclavicular joint and reinforcement of the capsular structures This, however has technical disadvantages. It is assumed that a hole can be drilled across the sternal end *of the articulation and* that the

roof of this tunnel will still be sufficiently strong to provide firm fixation We have not found this to be true The anterior wall of the sternum is relatively thin and fragile and little strength remains in the roof of the tunnel following the drilling of a large hole

In the Bankart procedure an osteoperiosteal flap is turned down from both sides of the joint two holes are drilled in an anteroposterior direction through the posterior portion of the sternum and clavicle Through these holes a fascial strip is looped in a modified mattress suture arrangement The osteoperiosteal flaps are then sutured in place This method does not provide firm fixation.

Bunnell has described a technic wherein a continuous strip of fascia is utilized to loop the joint as well as to form a loop around the clavicle and the first rib The loop is reinforced by removable stainless steel wire to provide rigid fixation while the fascia heals.

All of the operations for recurrent dislocation of the sternoclavicular joint are rather involved and difficult Because of the important structures which lie in the immediate vicinity of the operative field, the technic must be meticulous and slow One will best avoid trouble in the region of the sternoclavicular joint by dissecting close to the bone Holes drilled through bone in this region should be placed so that the point of entrance and exit may be visualized.

Technic (Bunnell) —The clavicle and sternum are exposed through a transverse incision immediately below the sternoclavicular joint. The tissues are dissected back from the clavicle and the manubrium after carefully clearing it subperichondrally to avoid the pleura a carrier is passed around the first costal cartilage A hole five millimeters in diameter is drilled anteroposteriorly through the manubrium and clavicle on each side of the sternoclavicular joint and a No 22 stainless steel wire is threaded through these holes. A strip of fascia lata, twelve inches by one-half inch, is next passed through the hole in the manubrium brought out from behind carried over the top of the clavicle to the anterior surface of the operative field thence down under and up from behind the first costal cartilage behind the clavicle it is looped over the first strand and brought out through the hole drilled in the clavicle The fascia is then drawn taut crossed tightly over the front of the joint and fastened together by running stitch of No. 30 stainless steel wire The ends of the latter wire are brought out through the skin and fastened by a shot on each end

After Treatment.—The loop of adhesive about the elbow is fastened to a belt of adhesive plaster This is the only immobilization used and should be continued for a period of approximately three weeks. The kinked wire is then removed and graduating exercises and active resumption of the use of the arm are begun

Technic (J B Speed) —Beginning at a point about one-half inch lateral to the midline of the sternum an incision two and one-half inches in length is made parallel to the lower border of the medial portion of the clavicle The clavicle is completely denuded of all soft tissue attachments over an area of approximately two inches. A portion of the pectoralis major muscle is next detached and retracted laterally and distally in order to expose the first and second ribs By subperiosteal dissection preferably with a rib stripper the first rib and rib cartilage are exposed roughly over an area comparable to the denuded area of the clavicle This step in the procedure must be carried out slowly

apposition with the tibia. If this position cannot be satisfactorily maintained, however, a rustless steel nail or screw may be inserted.

After Treatment.—(See p 291)

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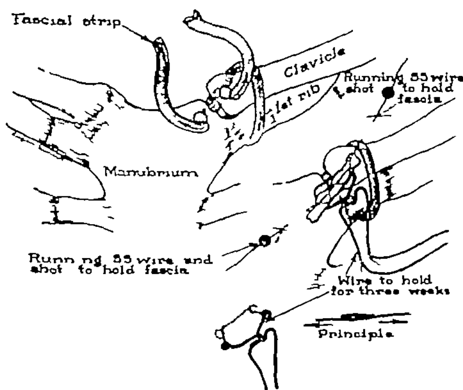


Fig 6.—Bunnell operation for dislocation of sternoclavicular joint. Fascial repair is reinforced by a kinked, removable stainless steel wire fastened outside the skin with two shot. After healing of fascia is complete (three weeks) kink is released by pulling on each end, and wire is removed (From Bunnell, S. Surgery of the Hand, Philadelphia, 1944 J B Lippincott Co)

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After Treatment.—The loop of adhesive about the elbow is fastened to a belt of adhesive plaster This is the only immobilization used and should be continued for a period of approximately three weeks. The kinked wire is then removed and graduating exercises and active resumption of the use of the arm are begun

Technic (J S Speed).—Beginning at a point about one half inch lateral to the midline of the sternum an incision two and one-half inches in length is made parallel to the lower border of the medial portion of the clavicle The clavicle is completely denuded of all soft tissue attachments over an area of approximately two inches. A portion of the pectoralis major muscle is next detached and retracted laterally and distally in order to expose the first and second ribs By subperiosteal dissection preferably with a rib stripper the first rib and rib cartilage are exposed roughly over an area comparable to the denuded area of the clavicle. This step in the procedure must be carried out slowly

and the dissection must be close to the bone. An aneurysm needle is now passed around the first rib and a piece of silk, to which is attached a *strip of fascia* lata approximately one-half inch wide and eight inches long, is threaded through the eye of the aneurysm needle. The loop of fascia is drawn around the rib and, in a similar manner looped around the clavicle at the approximate level of the costoclavicular ligament. The procedure is then repeated to form a double loop of fascia about the clavicle and first rib. The ends of the fascia are then tied together and reinforced with silk sutures. At this stage, the joint will seem fairly secure. For additional stability a second loop is passed around the first rib. A hole is then drilled in a vertical plane through the clavicle being so placed that the site of entrance and exit of the drill may be seen; this should be approximately one-half inch lateral to the medial tip of the clavicle. Finally the end of the second loop of fascia is threaded through the hole in the clavicle and tied on itself.

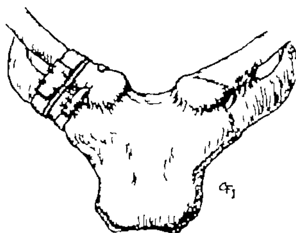


Fig. [illegible].—Repair of dislocation of sternoclavicular joint (J. S. Speed). Fascia looped through hole drilled in clavicle and around first rib supplemented by double loop of fascia one-inch lateral to joint.

If the proximal end of the clavicle is displaced distally so as to overlap the first rib completely and make its exposure difficult, Allen's operation, wherein *the clavicle is anchored to the second rib may be employed.* The fascial strip is looped through a hole drilled in the clavicle as in the second part of the above procedure. The end of the fascial loop is then passed around the second rib or through a hole drilled in the second rib. There are two disadvantages, however, to the Allen operation. The second rib frequently is not sufficiently close to the clavicle; in this event a long piece of fascia is required to traverse the distance between the clavicle and the second rib. Being unduly long, the fascia may stretch and expand. Further, the general plane of this check ligament is more vertical than anteroposterior and the latter is preferable.

After Treatment.—The arm is immobilized in a Velpeau dressing for a period of three weeks. Subsequently physical therapy and graduated exercises are instituted.

Excision of the Medial End of the Clavicle

If reconstruction procedures for dislocation fail, excision of the medial end (one to one and one-half inches) of the clavicle provides a satisfactory func

tional result. With degenerative lesions of the sternoclavicular joint secondary to trauma or inflammation resection is the only practical means of relieving symptoms, arthrodesis is not practicable

Technic.—The mesial end of the clavicle is exposed subperiosteally through an incision two and one-half inches in length After freeing its mesial end at the sternoclavicular joint the clavicle is grasped with forceps, lifted upward and cleared of soft tissue investments posteriorly *After resection of the mesial* end of the bone the periosteal envelope is reefed and closed, as in Darrach's resection of the ulna (Fig 431)

After Treatment.—The shoulder girdle is immobilized by a Velpeau dressing for three weeks.



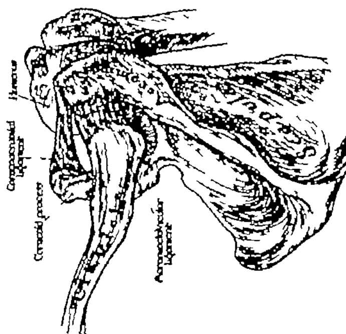
Fig. 384 —Before and after operation for dislocation of sternoclavicular joints.

Dislocation of the Acromioclavicular Joint

Unless the coracoclavicular ligament is severed, upward displacement of the lateral end of the clavicle is slight thus, symptoms are seldom so severe as to warrant surgical interference If the dislocation is complete some form of surgical intervention is warranted as conservative measures can be relatively im practicable and their results uncertain From a study of 41 patients Urist made the following two important diagnostic and prognostic observations an increase in width of the joint space in an anteroposterior roentgenogram indicates posterior displacement of the clavicle, even though the superior and inferior rela tionships of the acromion and clavicle are established that if posterior displacement and abnormal mobility of the clavicle is present three weeks after injury conservative treatment will probably fail It was his observation that the chief obstacle to conservative treatment was the interposition of the meniscus, frayed capsular ligaments, or flakes of articular cartilage

Fundamental requisites for a satisfactory repair of complete dislocation of the acromioclavicular joint are (1) a ligament must be re-established be-

tween the clavicle and the coracoid process (2) temporary metallic fixation must be used until the new ligament is healed otherwise the fascia will stretch and allow subluxation of the joint. The use of metal fixation alone, or fascial loops alone is inadequate Murray and Phemister have inserted wires across



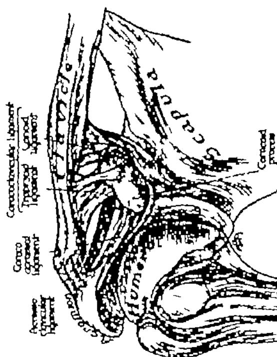
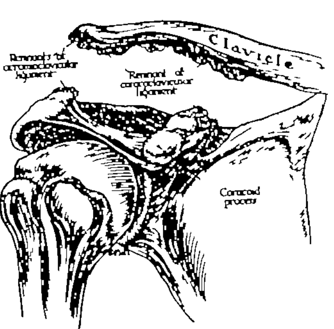


Fig [illegible].—Coracoclavicular and acromioclavicular ligaments are principal stabilizing factors of acromioclavicular joint. (From Henry M. O Minnesota Med. [illegible] 431, 19[illegible].)

the acromioclavicular joint Since the cross section of the acromion and clavicle is small the wires should be small wires across movable joints may migrate, bend break, or pull out of the bone. Bosworth in this country and Vere-Hodge in England independently employed fixation by means of a screw in-



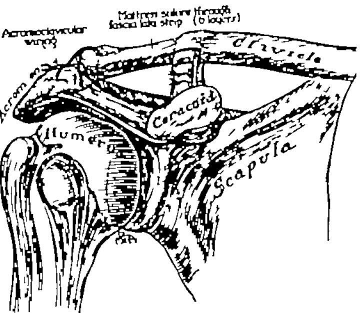


Fig 206.—*A* Separation of acromioclavicular joint, with rupture of stabilizing ligaments. *B* Repair by fascial loop over clavicle and around coracoid process. Wire across acromioclavicular joint is principal stabilizing factor until ligaments heal. (From Henry M O., Minnesota Med. 12 431 1929)

serted vertically through the clavicle into the coracoid process. Urist points out that arthrodesis of the acromioclavicular joint is unacceptable since the clavicle rotates on its longitudinal axis during certain motions of the shoulder and arthrodesis interferes with motion above 90 degrees. The same objections are offered to fixation by a lag screw inserted through the clavicle into the coracoid process.

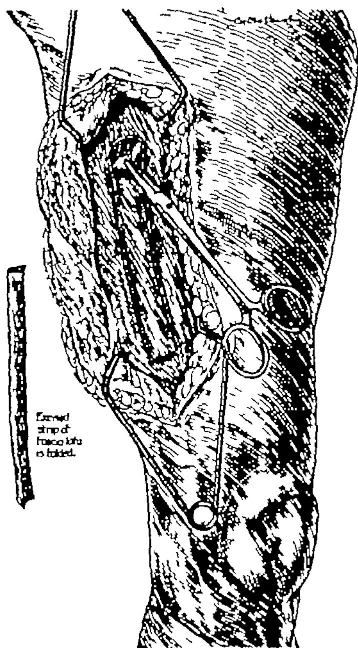


Fig. 167.—Fascial strip for new coracoclavicular ligament obtained from thigh. (From Henry M. O. Minnesota Med. 12: 431, 1929.)

We utilize two operative procedures reconstruction of the ligaments, or excision of the outer end of the clavicle Henry's operation has been objected to for the reason that it does not reconstruct the capsular ligaments, which apparently are so important Theoretically this is a valid objection. Practically however, after reconstruction of the coracoclavicular ligaments, and wiring of

the acromioclavicular joint fibrous tissue forms across this joint, uniting the frayed ends of the acromioclavicular ligaments and capsule Other than a firm fixation the use of wire instead of fascia across the acromioclavicular joint has another advantage a bulky structure is not inserted in the tight subacromial space thereby decreasing the amount of residual postoperative stiffness reported by some surgeons. The Henry procedure, we feel is applicable to young athletes, particularly football players Excision of the outer end of the clavicle is preferred if the dislocation is of more than one month's duration or if the lesion occurs in a middle-aged or elderly individual Reduction of old dislocations, particularly in manual laborers or athletes, does not relieve pain and a residual arthritis is inevitable the symptoms from this lesion may be more disabling than from an unreduced dislocation

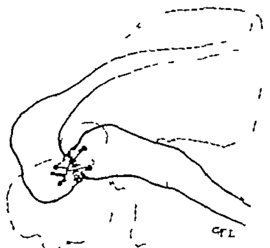


Fig. 265.—Method of placing wire loop across acromioclavicular joint for stable fixation after ligaments heal (4 to 6 weeks) wire should be removed.

Much has been written recently on the portions of the skeleton which are dispensable While it is true that the clavicle or portions of the clavicle may be dispensed with we need not assume that the clavicle has no function whatever In fact, after resection of the outer end of the clavicle particularly in young athletes there is little question that some minor degree of disability is present Urist observed that the cosmetic result is satisfactory but that neither the function nor the appearance can be described as normal His studies indicate that the clavicle acts as a yard arm (this is contrary to Gurd's contentions) which prevents the shoulder from falling anteriorly and inferiorly on the chest wall while the musculature about the shoulder compensates to a degree for the instability incident to loss of the end of the clavicle practically all patients who subject their shoulders to hard, manual labor or prolonged vigorous exercise will note some weakness or easier fatigue as compared with the normal shoulder

Technic (Henry).—An incision is made over the coracoid process curving upward and laterally along the clavicle and over the acromioclavicular joint. The periosteum is elevated from the clavicle in the approximate region of the coracoid tuberosity and the coracoid process is exposed and stripped of the remnants of the coracoclavicular ligaments A strip of fascia lata, 2 cm in width and 14 cm in length is removed from the thigh The fascia is folded upon itself to form a double-thickness ligament (Fig 266) then passed beneath the base to the coracoid process and up over the clavicle but beneath the perios

tourn The dislocation having been reduced, the ends of the fascial band are overlapped and held taut while being fastened in place with mattress sutures. The acromioclavicular joint is fixed by a stainless steel wire loop (Fig 268)

After Treatment—Immobilization is maintained for a period of four weeks, and is followed by graduated exercises and physical therapy The stainless steel wire loop is removed ten weeks after operation

Technic (Bunnell)—The acromioclavicular joint, the outer three inches of the clavicle and the coracoid process are exposed by an L-shaped incision with its apex one inch anterolateral to the joint and the long arm extending proximally along the lower border of the clavicle. Three holes, each 5 mm. in diameter are drilled as follows the first through the tip of the acromion slightly anterior to the center of the joint, the second, through the clavicle lateral and slightly posterior to the center of the joint, and the third, through the clavicle at the outer border of the coracoclavicular ligament. A segment of

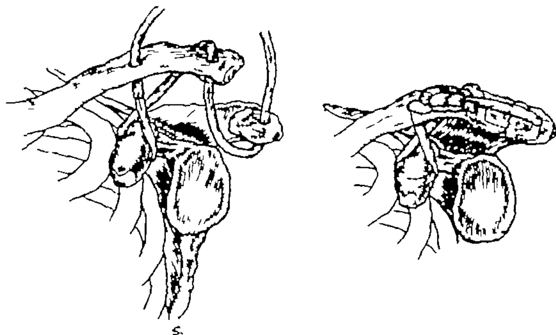


Fig 200.—Bunnell technic of repair of acromioclavicular dislocation. Fascia is reinforced by kinked wires (see Fig 104)

No 22 stainless steel wire is threaded through holes one and two Another loop encircles the clavicle and coracoid. A strip of fascia lata ten inches long and 1 cm wide is threaded down through the hole in the acromion (No 1) and up through the lateral hole in the clavicle (No 2) The strip is then carried over and behind the clavicle beneath the coracoid process from within outward, and up through the proximal hole (No 3) in the clavicle The dislocation is then reduced and the position maintained by kinking the wire loops (Fig 104) The ends of the wire are brought out through the skin. The ends of the fascial strip are drawn tightly and sutured in place over the joint with a running removable suture.

After Treatment.—The joint is fixed in a Sayre strapping for one month. The patient is confined to bed during the first two weeks following operation. After removal of the dressing function is cultivated by active and passive exercises. The wire loops that hold the bones in place are removed one month postoperatively

Excision of the Outer End of the Clavicle

Mumford and Gurd independently and simultaneously arrived at the same conclusions in chronic dislocations of the acromioclavicular joint, function may be improved and convalescence shortened by resection of the outer end of the clavicle loss in continuity in the shaft of the clavicle is still consistent with a stable painless shoulder and a normal range of motion

If the coracoclavicular ligament is intact the end of the clavicle lateral to this ligament is resected if, however the upward displacement of the clavicle is complete, incident to a rupture of the coracoclavicular ligament, the Mumford and Gurd procedure should be combined with a fascial repair of the coracoclavicular ligament

Technic (Mumford and Gurd) —The outer end of the clavicle is exposed through a small curved incision The distal inch or one and one half inches, of the clavicle is freed from all soft tissue attachments by subperiosteal dissection, and with bone-cutting forceps the distal end is removed The cartilaginous surface of the acromion is left undisturbed The raw surface on the end of the clavicle is covered by reefing and suture of the periosteal envelope and soft tissues over its end

After Treatment.—The shoulder is immobilized by a Velpeau dressing for a period of one week Active use is then encouraged. Under ordinary conditions, a return of full function may be expected within four weeks.

Unreduced Anterior Dislocation of the Head of the Radius

Old dislocations of the head of the radius occasionally are compatible with a moderate degree of function of the elbow although the joint is weak and the carrying angle of the elbow is increased. Further, adhesions form about the displaced head scar tissue may be present between the head of the radius and the articular surface of the ulna and the head may become elongated making reduction impossible This condition is observed in adults following dislocations which have occurred in childhood If these changes are of a minor degree reduction is accomplished and the orbicular ligament reconstructed as described for acute dislocation of this joint (p 303)

Excision of the head of the radius is preferable if the displacement cannot be satisfactorily corrected (p 494) After excision, attachment of the upper extremity of the shaft of the radius to the ulna by transplants of fascia lata may be necessary These operations never adversely affect the strength or function of the arm and usually increase its usefulness.

Dislocations of the Distal Radio-Ulnar Joint

Milch notes that prominence of the ulnar head, associated with weakness of the grip and weakness of the wrist pain or tenderness over the distal radio-ulnar joint, or a clicking sensation in this region on rotation of the forearm may be caused by a number of factors

1 Injury to the triangular fibrocartilage
2 Injury to the ulnar collateral ligament
3 Rupture of the radio-ulnar ligaments
4 Axial deviation of either of the forearm bones
5 Disproportion in length of the forearm bones
6 Enlargement or disease of the head of the ulna

Indiscriminate resection of the distal end of the ulna for derangement of the wrist does not take into account the various etiologic factors that may produce this condition, nor the importance of the ulnar head. Milch stresses that the ulnar head should be spared, when possible and attention directed toward the repair or reconstruction of the primary lesion To undertake repair of the soft tissues alone, however without correction of axial deviation or disproportions in length of the forearm bone, would be misplacing Milch's emphasis upon the multiple factors which may be responsible for dorsal prominence of the distal end of the ulna (see malunited Colles fracture, Madelung's deformity cessation of growth of the distal radial epiphysis, atrophic arthritis of the wrist)

Milch describes the repair utilized in one case wherein the ulnar collateral ligament and the triangular fibrocartilage were apparently involved. Repair consisted of suture of a fractured styloid and a torn triangular cartilage to the ulna

In addition to the above described injury Milch states that the inferior radio-ulnar ligament may also be ruptured. Disabilities from this source are somewhat similar to those mentioned above, although the roentgenograms usually disclose diastasis of the distal radio-ulnar joint with normal length of the bone. This, he states, is a pathognomonic sign and is an indication for repair of the radio-ulnar ligament. Fascial loop operations are designed to accomplish this purpose In 1926 Milch described a technic of fascial repair which was later modified by Eliason and Lowman Milch emphasizes the fact that the fascial loop operations are designed only to reconstruct abnormal ligament structures, and cannot be successful unless normal bony relationships are previously established

Primary repair of the ligaments about the radio-ulnar joint is indicated in few cases, and reconstruction of the ligaments (p 592) in even fewer Rupture of these ligaments without an associated fracture is ordinarily dismissed as of sprain of no consequence. Unless fractures are visualized in the roentgenograms, inadequate immobilization is usually employed If the ligaments of the wrist do not heal properly this is seldom discovered before the elapse of six weeks by this time, arthritic change will generally be sufficiently marked and the degeneration of the articular cartilages so far advanced that re-establishment of the normal radio-ulnar relationships would not be particularly desirable. The pain and disability attendant upon the traumatic arthritis would exceed that produced by a resection of the distal end of the ulna. Only rarely therefore, is *reconstruction of the ligaments advisable*

PATHOLOGIC DISLOCATIONS

The term pathologic dislocation is applied to all dislocations wherein trauma is not the primary factor [Congenital and paralytic dislocations (Chs. XXV and XXII) are not herein considered as pathologic dislocations.] A variety of affections may be the cause

1 Stretching of the capsule and ligaments by exudates associated with pyogenic arthritis.

2 Destruction of articular surfaces from neoplasms, osteomyelitis, tuberculosis, or trophic arthropathies (Charcot joints)

The reader will find a concise presentation of procedures applicable to pathologic dislocation under Acute Infectious Arthritis of the Hip (p 212), which is one of the more common offenders

References

Adams, J C.: Review of 180 Cases of Recurrent Dislocation of the Shoulder, J Bone & Joint Surg 30-B 26 1948

Adams, John D Displacement of the Semilunar Carpal Bone An Analysis of 12 Cases, J Bone & Joint Surg 7 665 1925

Albee Fred H: The Bone Graft Wedge in the Treatment of Habitual Dislocations of the Patella M Rec. 88 257, 191

Allen A W: Living Suture Graft in Repair of Fractures and Dislocations Arch Surg 16 100, 1928

Anderson, R L. Dislocations of the Knee Report of Four Cases, Arch. Surg 46 508 1943.

Ashhurst A P C Recurrent Unilateral Subluxation of the Mandible. Excision of the Interarticular Cartilage in Cases of Snapping Jaw Ann Surg 73 712 1921

von Baeyer H Translocation of Tendons. Forty Ninth Report of Progress in Orthopedic Surgery p. 1. (Abst from Zentralbl. f Chir 58 3140 1932.)

Bankart A S. B An Operation for Recurrent Dislocation (Subluxation) of the Sternoclavicular Joint Brit J Surg 26 320 1938

— The Pathology and Treatment of Recurrent Dislocation of the Shoulder-Joint, Brit. J Surg 26 23 1938.

Bankart A. S B.: The Pathology and Treatment of Recurrent Dislocation of the Shoulder Joint Brit J Surg 26 23 1938

Banks S. W Aseptic Necrosis of the Femoral Head Following Traumatic Dislocation of the Hip A Report of Nine Cases J Bone & Joint Surg 23 753 1941

Bennett G L. Old Dislocations of the Shoulder J Bone & Joint Surg 18 594 1936

Bloom F A Wire Fixation in Acromioclavicular Dislocation J Bone & Joint Surg 27 273 1945.

Bost Frederick C., and Inman Verne T The Pathological Changes in Recurrent Dislocation of the Shoulder A Report of Bankart's Operative Procedure, J Bone, Joint Surg 24 595 1942.

Bosworth, Boardman M Acromioclavicular Separation; New Method of Repair, Surg., Gynec. & Obst. 73 866, 1941

Brackett, E. G: Operation for Habitual Dislocation of the Patella. Third Report of Progress in Orth. Surg., p 25, and Ninth Report of Progress in Orth Surg., p 18

Bunnell Sterling Fascial Graft for Dislocation of Acromioclavicular Joint Surg Gynec Obst 46 563 1928

Bunnell Sterling Surgery of the Hand Philadelphia 1944 J B. Lippincott Co

Burman M S. Subluxation of the Head of the Fibula Am J Surg 11 108 1931

Campbell, Willis C: A Textbook of Orthopedic Surgery Philadelphia, 1930 W B Saunders Co.

— Dean Lewis Practice of Surgery Vol. 3 Chap 3 Hagerstown 1927 W F Prior Co., Inc.

—: Perineal Dislocation of the Hip J A. M. A. 78 1115 1922.

—: Posterior Dislocation of the Hip Joint With Fracture of the Acetabulum, J Bone & Joint Surg 18 842, 1936.

Campbell, W C., and Smith, H. Dean Lewis Practice of Surgery Hagerstown, Md., 1940 W F Prior Co., Inc.

Cave, E. F: Retrolunar Dislocation of the Capitate With Fracture or Subluxation of the Navicular Bone, J Bone & Joint Surg. 23 830, 1941

Cave E. F and Rowe, C R. Capsular Repair for Recurrent Dislocation of Shoulder Pathologic Findings and Operative Technic, S. Clin. North America 27 1289, 1947

Clairmont, P Ueber neue Operationsmethoden bei habitueller Schulterluxation, Wien klin. Wchnschr 30 1507 1917

Conwell, H. E. Dislocations of the Knee Joint, Am. J Surg. 43 492, 1939

Conwell, H. E., and Alldredge R H. Dislocations of the Knee Joint, J A. M A. 106 1252 1936.

Cotton, F J Dislocations and Joint Fractures, Philadelphia 1910 W B Saunders Co., p. 534

Cox, F J Anterior Dislocation of the Distal Extremity of the Ulna, Report of Case Surgery 12 41, 1942

Cubbins, Wm. R., Callahan, J J., and Scuderi, C. S: The Reduction of Old or Irreducible Dislocations of the Shoulder Joint Surg. Gynec. Obst. 58 129 1934

Darrach, W Anterior Dislocation of the Head of the Ulna Ann. Surg. 56 802 1912.

Darrach W Habitual Forward Dislocation of the Head of the Ulna Ann. Surg 57 928 1913.

Davis, Carl B Recurrent Dislocation of the Patella, S. Clin. Chicago 3 291 1919

Davis, Geo. G: Treatment of Dislocated Semilunar Carpal Bones, Surg. Gynec. Obst. 37 225 1923.
Desnaint, J J Sur l adaptation fonctionelle dans les luxations anciennes antéro-internes de l épaule Rev d orthop 15 508, 1928.
Dollinger, J The Reposition of Inveterate Traumatic Luxation of the Hip-Joint, Ann. Surg. 55 176 191*
Downing F Harold A Simplification of Bankart s Capsulorrhaphy for Recurrent Dislocation of the Shoulder J Bone & Joint Surg 28 230, 1946.
Eden R. T Operative Treatment of Habitual Dislocation of the Shoulder Zentralbl. f. Chir 47 1002, 1920
Gallie, W E., and LeMesurier A. B: Habitual Dislocation of the Patella, J Bone & Joint Surg. 6 575 1924
Goldthwait, Joel E: Permanent Dislocation of the Patella, Ann Surg. 29 62, 1899
— Slipping or Recurrent Dislocation of the Patella. With the Report of Eleven Cases, Boston M & S. J 150 169 1904
Gosman, Joseph A. Recurrent Dislocation of the Ulna at the Elbow J Bone & Joint Surg 25 448, 1943
Gurd, F B: The Treatment of Complete Dislocation of the Outer End of the Clavicle, Am. Surg 113 1094, 1941
Hart, Vernon L. Fracture-Dislocation of the Hip J Bone & Joint Surg 24 458, 1942.
Hauser Emil D W Total Tendon Transplant for Slipping Patella. New Operation for Recurrent Dislocation of the Patella Surg Gynec. Obst 66 199 1938.
Henderson, Melvin S. Habitual Dislocation of the Shoulder J A. M. A. 95 1653 1930.
— Results Following Tenosuspension Operations for Habitual Dislocation of the Shoulder J Bone & Joint Surg 17 978 1935
—: Tenosuspension for Habitual Dislocation of the Shoulder Surg. Gynec. Obst. 43 18 1926.
Henderson, M. S. Tenosuspension Operation for Recurrent or Habitual Dislocation of the Shoulder, S. Clin North America 23 997 1943.
Henry A. K., and Bayumi, M Fracture of the Femur With Luxation of the Ipsilateral Hip Brit. J Surg 22 204 1934.
Henry M. O Acromio-Clavicular Dislocations, Minnesota Med. 12 431 1929
Hindenach, J C. R.: Recurrent Posterior Dislocation of the Shoulder J Bone & Joint Surg 29 582, 1947
Hobart, M. H. Recurrent Dislocation of the Shoulder, Am. J Surg 43 279 1939
Hobart, M. H., and Garrison M. Open Reduction of Old Dislocation of the Head of the Humerus: Importance of Complete Mobilization of the Head J Bone & Joint Surg 17 199 1935.
Hofmann K.: Surgery of Habitual Shoulder Luxation, Zentralbl. f. Chir 51 858, 1924
Jones, Sir Robert, and Lovett, Robert W Orthopedic Surgery New York, 1924, Wm. Wood & Co
Kapel O The Operative Treatment of Recurrent and Chronic Dislocation of the Patella With Especial Reference to the Operations of Krogius and Goldthwait Acta chir Scandinav 77 201 1935
Key John Albert, and Conwell, H. Earle The Management of Fractures Dislocations and Sprains, ed 3 St. Louis, 1942, The C. V Mosby Co.
King Don, and Richards, Victor Fracture-Dislocations of the Hip Joint J Bone & Joint Surg 23 533 1941
Krogius, A. Zur operativen Behandlung der habituellen Luxation der Kniescheibe, Zentralbl. f Chir 31 254 1904
Levine, Max A. A Treatment of Central Fractures of the Acetabulum, J Bone & Joint Surg 25 902 1943
Lowman C L.: The Use of Fascia Lata in the Repair of Disability at the Wrist J Bone & Joint Surg 12 400 1930.
Lowman, C. L. Operative Correction of Old Sternoclavicular Dislocation J Bone & Joint Surg. 10 740, 1928
MacAusland W R Perilunar Dislocation of the Carpal Bone and Dislocation of the Lunate Bone, Surg., Gynec. & Obst. 79 256 1944.
MacAusland, W R. Recurrent Dislocation of the Shoulder Surg. Gynec Obst. 38 739 1924
MacAusland, W R and Sargent, A. F Recurrent Dislocation of the Patella, Surg Gynec. Obst. 35 35, 1922
Mahorner, H. R. and Mead, W H. Operation for Dislocated Semilunar Bone of the Wrist, Surgery 5 249 1939
May H. Nicola Operation for Posterior Subacromial Dislocation of the Humerus, J Bone & Joint Surg 25 78, 1943
Mayer Leo Recurrent Dislocation of the Jaw J Bone & Joint Surg 15 889 1933.
McBride, Earl D Dislocation of the Semilunar Bone, Arch. Surg 14 684, 1927
McCarroll, H. R. and Schwartzmann John R. Lateral Dislocation of the Patella, Correction by Simultaneous Transplantation of the Tibial Tubercle and Semitendinosus Tendon. J Bone & Joint Surg 27 446 1945.

McWhorter G L. Old Posterior Dislocation of the Shoulder with Complete Disability Reduction by Author s Posterior Shoulder Incision Technic of Applying Shoulder Spica, S. Clin North America 12 1339 1932.
Meyerding H W The Treatment of Acromioclavicular Dislocation S. Clin North America 17 1199 193.
Milch, Henry Bilateral Recurrent Dislocation of the Ulna at the Elbow, J Bone & Joint Surg 18 777, 1936.
Milch, H.: Cuff Resection of the Ulna for Malunited Colles' Fracture J Bone & Joint Surg. 23 311, 1941
Milch, H: Dislocation of the Inferior End of the Ulna Suggestions for New Operative Procedure, Am. J Surg 1 141, 1926.
Milch, H.: So-Called Dislocation of the Lower End of the Ulna, Ann. Surg. 116 282, 1942.
Milch Henry Recurrent Dislocation of the Thumb Capsulorrhaphy Am. J Surg. 6 237 1929
Miltner Leo J., and Wan F K. Old Traumatic Dislocation of the Hip, Surg., Gynec. Obst. 56 84 1933
Mitchell Jos. I: Dislocation of the Knee, J Bone & Joint Surg 12 610 1930
—: Total Dislocation of the Astragalus J Bone & Joint Surg 18 212, 1936.
Moroney, P B. A Technic of Drilling the Glenoid in Bankart's Operation for Recurrent Dislocation of the Shoulder, Brit. M. J 2 122 1945.
Morris, J H.: Chronic Recurring Temporomaxillary Subluxation, Surg Gynec. Obst. 50 483, 1930.
Mumford, E. B.: Acromioclavicular Dislocation, A New Operative Treatment, J Bone & Joint Surg 23 99 1941
Murray Gordon: Fixation of Dislocations of the Acromioclavicular Joints and Rupture of Coracoclavicular Ligaments, Canad. M. A. J 43 270, 1940
Nicola T: Personal communication, 1948.
Nicola, Toufick Recurrent Anterior Dislocation of the Shoulder, J Bone & Joint Surg 11 128, 1929
—: Recurrent Dislocation of the Shoulder J Bone & Joint Surg 16 663 1934.
Osmond-Clarke H.: Dislocation of the Knee-Joint With Capsular Interposition Proc. Roy Soc. Med. 35 459 194_
Osmond-Clarke, H. Habitual Dislocation of the Shoulder J Bone & Joint Surg 30-B 19 1948
Parker Chas. A. Congenital Dislocation of the Patella, S. Clin Chicago 4 859 1920.
Phemister Dallas B The Treatment of Dislocation of the Acromioclavicular Joint by Open Reduction and Threaded Wire Fixation J Bone & Joint Surg 24 166, 1942.
Platt, H. Traction Lesions of the External Popliteal Nerve Lancet 2 612, 1940.
Platt H. On the Peripheral Nerve Complications of Certain Fractures, J Bone & Joint Surg. 10 403, 1928.
Potts, F N., and Obletz, B. E. Aseptic Necrosis of Head of Femur Following Traumatic Dislocation, *J Bone & Joint Surg* 21 101, 1939
Pringle, J H.: Displacement of the Mandibular Meniscus and Its Treatment, Brit. J Surg 6 385 1918 19
Putti, V The Treatment of Central Luxation of the Femur Internat. Abst. Surg 46 184 1928 (Abstracted from Chir d. org di movimento 11 530 1927)
Reichenheim, P P Transplantation of the Biceps Tendon as a Treatment for Recurrent Dislocation of the Elbow Brit. J Surg 35 201 194_
Reiss, George I. An Instrument for Use in the Bankart Operation for Recurrent Dislocation of the Shoulder J Bone & Joint Surg 29 812, 1947
Rich, E A The Check Ligament Operation for Recurrent Dislocation of the Shoulder, Northwest Med. 16 114 1917
Ritter Henry H. Dislocation of the Knee Joint With Report of a Case, J Bone & Joint Surg 14 391 1932.
Roberts, P W An Operation for Recurrent Dislocation of the Shoulder J Bone & Joint Surg. 15 233 1933.
Roberts, S. M Acromio-Clavicular Dislocation Am J Surg 23 322 1934
Robertson G A Method of Treatment for Habitual Dislocation (Congenital) of the Patellae, Surg. Gynec. Obst. 14 378 1912.
Robertson, Ross, and Stark, W J Diagnosis and Treatment of Recurrent Dislocation of the Shoulder J Bone & Joint Surg 29 797 1947
Selig Seth, and Shein, Albert Irreducible Buttonhole Dislocations of the Finger J Bone & Joint Surg 22 436, 1940
Shorbe, Howard B. Carpometacarpal Dislocations. Report of a Case J Bone & Joint Surg 20 454 1938
Slocum, Donald B Stabilization of the Articulation of the Greater Multangular and the First Metacarpal, J Bone & Joint Surg. 25 626 1943.
Smith, Hugh Subastragalar Dislocation J Bone & Joint Surg 19 373 1937
Speed, J S. An Operation for Unreduced Posterior Dislocation of the Elbow Southern M. J 18 193 19__.

Speed, Kellogg: Recurrent Anterior Dislocation of the Shoulder Operative Cure by a Bone Graft, Surg. Gynec Obst. 44 468 1927
Stanger, J Kenneth Fracture-Dislocation of the Thoracolumbar Spine, With Special Reference to Reduction by Open and Closed Operations, J Bone & Joint Surg. 29 107 1947
Stuck, W G., and Hinchey J J *Experimentally Increased Blood Supply to the Head and Neck of the Femur* Surg., Gynec. Obst. 78 160 1944.
Stuck, W G., and Vaughan, W H.: The Prevention of Disability After Traumatic Dislocation of the Hip, To be published. (Presented before the Southern Surgical Association, Hollywood, Florida, December 10 1947)
Thomas, T Turner Habitual or Recurrent Dislocation of the Shoulder; Forty Four Shoulders Operated on in Forty Two Patients, Surg Gynec. Obst. 32 291 1921
Urist, Marshall R.: Complete Dislocations of the Acromioclavicular Joint. The Nature of the Traumatic Lesion and Effective Methods of Treatment With an Analysis of *Forty-One Cases, J Bone & Joint Surg* 28 813 1946.
Venable Charles S. and Stuck, W G The Muscle-Flap Transplant for the Relief of Painful Monarticular Arthritis (Aseptic Necrosis) of the Hip, Ann. Surg 123 641 1946.
Vere-Hodge, N Coraco-Clavicular Fixation by Screw, recorded in Fractures and Joint Injuries Sir Reginald Watson-Jones, Baltimore 1946 The Williams & Wilkins Co.
Watkins, Jas. T An Operation for the Relief of Acromio-Clavicular Luxations, J Bone & Joint Surg 7 790 1925.
— Obturator Dislocations, J Bone & Joint Surg. 5 243 1923
Watson-Jones, Sir Reginald: Fractures and Joint Injuries, Baltimore, 1946, The Williams & Wilkins Co.
Wiltberger B. R., *Mitchell G. L., and Hedrick, D W: Fracture of the Femoral Shaft Complicated* by Hip Dislocation. A Method of Treatment J Bone & Joint Surg. 30-A 225 1948.

CHAPTER VIII

FRACTURES

The indiscriminate practice of open reduction and internal fixation without proper indications is a violation of well understood physiologic principles in the treatment of fractures. The majority of fractures may be reduced by closed measures, surgery should never be recommended unless definitely warranted. The advantages to be gained by open reduction must outweigh those of closed methods. Extraneous considerations such as the financial condition of the patient, must not be allowed to influence sound scientific judgment. All factors must be weighed at their true value if one is to arrive at the proper treatment for any individual case.

Developments in metallurgy surgical technic and antibiotic therapy within the past fifteen years have made open reduction with internal fixation the most practicable solution to many previously difficult or unsolved fractures. Progress in open methods has not simplified this general picture Now that a wide variety of treatment is available, indications and contraindications must be more definite and detailed. In many cases, the open method is now the conservative method.

The early overenthusiastic uses and applications of open reduction and internal fixation reflected considerable discredit upon the procedure. Published data of the end results of this form of treatment are now ample however to permit a definite estimate of its true value In succeeding pages, we shall try to be as definite as possible in outlining the indications for various procedures, and endeavor not to present open methods with prejudice

Principles of Treatment of Fractures by Open Methods.—A knowledge of the anatomic and physiologic factors involved in the healing of a fracture is a necessary requisite to treatment. Such knowledge assumes special significance in open methods of treatment. Even with due regard for atraumatic technic there is some disturbance of the healing process and injury of the periosteum and soft structures through which the fragments receive their blood supply Although removal of the periosteum with its accompanying circulation may be restricted to a minimum a commensurate area of necrosis in the ends of the fragments often ensues Before healing is complete the circulation must be restored in the avascular area above and below the fracture, and osseous regeneration of the necrotic portion must be fairly well established In regions wherein union of a fracture is notoriously slow one might better be content in some cases, with partial end to-end engagement and preservation of the circulation rather than sacrifice or interfere with healing by open restoration of perfect anatomic contour

In contemplating the ultimate outcome of the treatment of any fracture the following considerations must be constantly kept in mind (1) the primary object of the treatment of a fracture is to secure union function of the adjacent soft parts and joints is predicated upon union (2) Functional results are pro-

portionate to the alignment and position of the bones after healing is con
A certain amount of variation from the normal anatomy is compatibl
good function or even normal function. The limit of error decreases m
however *in fractures that involve joint surfaces, or are near to joints.* (3)
mobilization of soft parts or adjacent joints is a requisite for early ret
function of the entire extremity Any method of treatment for fracture
be weighed in the light of these three considerations, with emphasis on th
one all three factors, however are of paramount importance in deter
the final results. In certain cases, a fourth factor must be considered, n
maintenance or re-establishment of the local circulation, as in fracture
scaphoid bone or neck of the femur

By ordinary methods, immobilization of the fracture is not compatibl
early mobilization of the soft parts and adjacent joints. It is difficult to
these two requisites simultaneously In selected cases, however intramed
fixation may be the solution to this difficulty

Indications for Open Reduction.—To assume that one who is not well
in the treatment of fractures by conservative means can readily adapt h
to operative measures is a fallacy to assume that the open method is an al
tive to closed treatment and, perhaps, an easier one, is to disregard our em
upon definite indications. There are many cases wherein either closed or
reduction may be considered proper for the majority of fractures, how
either the one or the other is recognized as being the best means to a satisfa
end.

The failure of a closed reduction may be occasioned by (1) interposit
tissue between the fragments, (2) displacement of fragments by reflex
tracture of muscles, (3) constant motion from inability to fix the frag
firmly (4) or failure of reduction by mechanical forces such as lev
traction, and pressure Open methods are advantageous in that the frag
may be reduced more perfectly under direct vision, and if necessary int
fixation may be applied to maintain the reduction. In fractures wherein
union or delayed union is likely reduction and fixation may be supplem
by the addition of osteogenic factors, such as bone grafts, thus increasin
possibilities of union.

The purposes of open reduction, and the indications for the procedur
as follows

1 To promote union for example, fractures of the neck of the femur

2. To reduce mortality and morbidity as in internal fixation of trochan
fractures.

3 *When adequate reduction by closed methods* is impossible Examp
depressed, comminuted fracture of the tibial condyle.

4. When displacement, angulation or deformity are likely following cl
reduction. Example—fracture of the patella, Monteggia fracture.

5 *When closed methods, ordinarily successful* have been tried and
failed, as in fracture of the internal malleolus.

Disadvantages of Open Reduction.—By open reduction, a closed frac
is, in a manner changed to a compound fracture in a favorable environm
It must be assumed that anyone who utilizes open methods on fractures
already developed a technic which reduces the danger of infection to a minim

Consequently, while every conscientious surgeon will consider this complication in performing any open operation, it must assume a relatively minor role. Antibiotic therapy has provided an added safety factor in this regard. Antibiotics, however, should be considered as merely adjuncts to scrupulous surgical technic and sterile surroundings, rather than as a substitute.

The stripping of soft tissues away from the bone incident to exposure of the fragments, and possibly the insertion of internal fixation is a definite deterrent to union as opposed to nonoperative interference. This fact assumes major importance in the diaphyseal portion of a bone. Disturbance of the vascularity of the fragments may be sufficient to tip the scales in favor of a nonunion. This cannot be avoided though it may be minimized by the use of a careful technic and by limiting dissection strictly to essential requirements.

Another disadvantage in open reduction lies in the amount of scar tissue subsequently produced. This disadvantage is particularly evident if dissection must be carried through large muscular areas, such as the thigh, and around the hip. Scar tissue formed in the thigh may be so extensive as to interfere with muscle function and limit motion in adjacent joints. The formation of scar tissue may be largely prevented, however by properly placing skin incisions, limiting dissection of the deep structures to planes of cleavage, and when possible, avoiding muscle splitting incisions.

Materials introduced into wounds which are foreign to the normal anatomic structures also have a deleterious effect on the healing of bone, and induce foreign body reaction. Undue pressure upon bones by metallic appliances is not desirable. These factors have assumed less and less importance with use of the newer relatively inert metals and improved types of fixation.

It cannot be denied that some of the more formidable procedures, such as open reductions of the femur and operations about the hip carry a little graver outlook at the moment than a closed method might entail. The danger is materially reduced, however by adequate preoperative examination and preparation, and the administration of blood and plasma.

Time for Open Reduction.—When open reduction is necessary for a fresh fracture, the procedure should be carried out as soon as feasible. As a precaution against infection, the extremity should be prepared as for a selective orthopedic operation. fracture blebs, undue swelling, excoriations, or lacerations of the skin must receive attention. Two weeks may be allowed for this purpose, if necessary, without ill effect.

Murray is convinced that fracture healing follows a relative time schedule. Since interference with this process is undesirable, reduction should be carried out within the first few hours if it is practical or possible. It is a common observation that following open reduction three or more weeks after the fracture, healing is likely to take place more slowly than following earlier operation. If open reduction must be delayed for more than three weeks, the use of bone-grafting procedures as for nonunion may be advisable, provided the fracture is located in an area wherein slow union or nonunion is prone to ensue.

Regardless of the theoretical advantages of early open reduction i.e., within the first eight to twelve hours, there are certain practical advantages to operation before swelling, jutting and distention of the soft tissues have reached a maximum. lines of cleavage are more easily identified, dissection and exposure

are simpler, and reduction may be accomplished more easily than if one waits until the infiltration process has more or less fixed the soft tissues into an inelastic mass. It is also probable that the danger of infection is less in early reduction than in the delayed reduction. Unfortunately, there are many cases wherein early open reduction is not feasible because of adverse local or general conditions.

INTERNAL FIXATION OF FRACTURES

The discussion in the following section will be limited to the use of plates and screws and to intramedullary fixation. Since internal fixation of bones may also be necessary in malunited and ununited fractures, in leg-shortening operations, or following osteotomy, the various other methods are described in detail in the chapter on Surgical Technic.

Plate and Screws

Murray has admirably summed up the details of open reduction and internal fixation of fractures of the long bones by a plate and screws, as follows

The Skin Incision.—Exposure should be sufficiently long to provide adequate exposure with the least possible retraction. Adequate exposure facilitates reduction and internal fixation. Incisions heal from side to side and not from end to end. When possible, the skin incision should not be placed directly over a bone or bony prominence.

The Deep Structures.—When possible, the bone should be approached through intermuscular planes rather than through muscle bodies sharp dissection is preferable to blunt dissection. To avoid trauma, the deep structures should be handled with the utmost gentleness. Meticulous hemostasis is essential, but the use of ligatures should be restricted

The Periosteum.—The bone should be exposed by subperiosteal stripping Prior to this procedure, the soft tissue should not be dissected away from the periosteum. Unnecessary stripping of the periosteum should be avoided, only those areas of the fracture being exposed which are necessary for accurate reduction and for the application of internal fixation Every attempt is made to preserve soft tissue attachments to loose fragments.

The Bone.—After exposure, reduction is accomplished by bone skids or periosteal elevators and maintained by the use of a holding clamp At least two or three types of clamps, such as the Lambotte clamp Lane clamp or forceps, Rush clamp or large Oschner clamp (Fig 72), should be available in order to cover every possible situation. The bone plate chosen should be sufficiently heavy for the bone involved and its length should be approximately five times the diameter of the bone at the fracture site For the larger bones, a six-screw plate is preferable to a four-screw plate. The plate is bent to fit the contour of the bone and is held firmly against the bone by proper clamps. A drill which is just a little smaller than the shank of the screw, minus its threads, is then selected A hole that is too small may cause the screw to shear off or the excessive strain on the screw may cause it to break later For screws of ordinary size, a 1/8 inch drill is used for cortical bone, and a 7/64 inch for soft bone.

Holes are drilled through the bone at a right angle to the plate surface, every effort being made to hold the drill steady during the drilling process. A

self tapping screw is inserted in the line of the hole, while the screw is held in the line of the hole with a minimum of side-to-side motion The screw should protrude through the distal cortex by the length of its tap To determine accurately the proper length of the screw, the length of the drill is measured when resistance is encountered from the distal cortex the drill is then continued

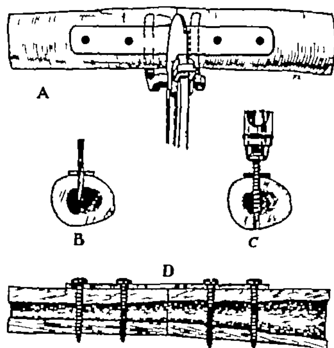


Fig. 270.—Internal fixation of a fracture with plate and screws. The screws must be snugly seated in the bone and must engage both cortices.

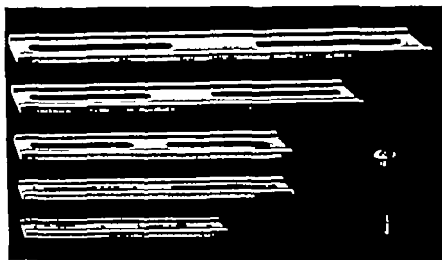


Fig 271.—Eggers slotted plate, designed to allow telescoping of the fragments. (Courtesy of Zimmer Manufacturing Co., Warsaw Ind.)

slowly until the resistance ceases and is again measured at this point This is the simplest method. A crochet hook is also commonly employed for measuring the depth of the hole. As each hole is drilled, a screw is inserted before proceeding to the next hole in the plate In short oblique fractures a screw is inserted at a right angle to the plane of the fracture to add further fixation After this procedure, fixation of the fracture should be relatively rigid The soft

parts particularly the periosteum, are then sutured carefully *over the bone and fracture site*. If difficulty is encountered in holding the fracture in satisfactory position by a clamp, the plate may be inserted on one fragment and held by one screw, the fracture is then reduced and the plate fixed by a screw placed in the opposite fragment. When a loose or third fragment is present, it should be accurately reduced and fixed into one of the shaft fragments. Thereafter the two shaft fragments are stabilized by a plate (Fig. 273*D*)



Fig. 274.—Appearance of femur after dual plates. Note hourglass constriction of bone with excessive callus of poor quality

Dual Plates and Screws.—Dual metallic fixation has little place in the treatment of fresh fractures of the shaft of the long bones. To apply the plate, a maximum amount of stripping of the periosteum is necessary This adversely affects the circulation to the two fragments. In addition, the pressure of the two plates on the bone appears to have some deleterious effects upon union and callus formation A dual plate may occasionally be indicated if the distal or proximal

fragment is relatively small and can be grasped by only one screw In this case the small fragment can be stabilized in the more or less clamp-like action of two plates.

Transfixion Screws—In long oblique or long torsional fractures, plates are usually unnecessary The fragments are properly apposed and transfixed by two or more screws at a right angle to the longitudinal axis of the bone In the presence of a butterfly fragment, whose two oblique surfaces are more or less equally distributed over both the proximal and distal fragment, two screws placed at a right angle to each other and obliquely to the longitudinal axis of the shaft may provide satisfactory fixation without a plate (Fig 273*B*)

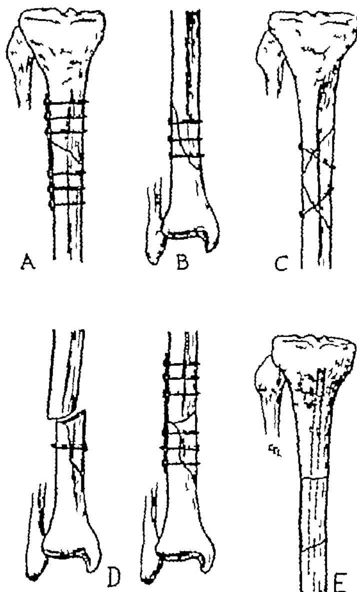


Fig. 273.—Technics of internal fixation. *A* Plate and six screws for transverse or short oblique fracture. *B* Transfixion screws. *C*, Transfixion screws for long butterfly fragment. *D* Fixation of fracture with short butterfly fragment. *E* Intramedullary fixation.

Intramedullary Fixation of Diaphyseal Fractures*

Intramedullary fixation is not a standard therapy in this country In Europe, however this procedure is well established beyond the experimental stage

* We acknowledge the assistance of Dr Hermann Fredenhagen of Basle, Switzerland, in the preparation of this section, and in the translation of the books written by Böhler and by Hübler

and is an accepted form of therapy In 1940 Gerhardt Küntscher reported a method of stable osteosynthesis by the insertion of pins in the intramedullary portion of long bones. He designed efficient pins for the tibia, femur, humerus, radius, and ulna, and despite early theoretical criticisms, firmly established and popularized the method Thus, although the principle of the intramedullary fixation was evolved by Lambotte, Küntscher should receive major recognition and credit for the procedure. The early work of L. V and H. L. Rush of Mississippi, should be acknowledged.

During World War II, Küntscher s technic apparently became the standard operation in the German Army English French and American surgeons observed some of the results in prisoners of war despite an appalling incidence of infection the method was viewed in a favorable light, particularly as applied to the femur After the war the procedure filtered into this country but it has been viewed with some reserve. It must go through some years of mellowing the pendulum of popularity will probably swing from side to side until (a) substantial series of cases by responsible investigators establish firmly the indications and contraindications for its use (b) the best methods of insertion and extraction of the pins are devised (c) surgical instruments and pins are improved (d) experiments are carried out to determine the reason for its effect on endosteal and periosteal callus and finally (e) a substantial series is compared with previous methods as to functional results

Many authors have published data relative to this method though these have not been sufficient to provide answers to the above problems. Häbler writes from an experience in 250 cases. Böhler has had wide experience with the method and has written a third volume to his previous well known treatise on fractures. Since he was working without the benefit of antibiotics, however his indications for its use may be modified accordingly Böhler recognized the adverse effects of intramedullary pinning on callus formation and the possible complications following poor technic in the insertion of the pin He did not quote comparative statistical studies In addition to these two substantial series, further information regarding the operation has been provided in reports by Soeur of Belgium, Mondor and Nardi of France, Westerborn, of Sweden, and others.

The perfect form of fracture therapy is one whereby the fracture is so firmly fixed in good position and alignment that the soft tissue structures and adjacent joints may be mobilized continuously during the process of healing There is no such form of therapy In selected cases, however a close approach may be found in intramedullary fixation

Advantages of Intramedullary Fixation.—Intramedullary fixation offers a really excellent mechanical fixation which prevents displacement of the fragments. The method presents several possible advantages over other forms of fixation, such as plates or screws immobilization in plaster, or the use of skeletal traction. In properly selected cases, fixation will be sufficiently rigid and strong to dispense with external immobilization Thus, muscle atrophy and restriction of joint motion will be less, convalescence will be shorter, and residual disability less. A substantial series of cases treated by intramedullary fixation may show that nonunion from internal fixation will be less than by previous

methods. This is based upon the presumption that with intramedullary fixation absorption at the ends of the fragments at the fracture site will present a less serious complication than following the use in many rigid forms of fixation. It is anticipated that weight bearing will cause the fragments to telescope on the intramedullary pin, thereby taking up the slack at the fracture site as rapidly as the ends absorb. Normal muscle tonicity will have the same effect on the bones of the upper extremity.

If it should prove efficient, the use of intramedullary fixation will provide advantages over the use of present forms of therapy from a military standpoint. To be able to dispense with casts or splints in tropical or frigid zones will be an obvious advantage. The ability to get about in an emergency would be an advantage in transporting patients, either by ship or by air. Obviously, a larger number of patients could be transported in the same amount of space with a minimum amount of cumbersome apparatus. There would be a maximum efficiency in the event of a dire emergency, such as the torpedoing of a ship or crash landing of an airplane. Further, it is possible that the convalescent period could be reduced by half. This, of course, would save many hospital days and much expense. These same advantages apply, with variations, to civilians.

Disadvantages of Intramedullary Fixation.—Inasmuch as epiphyses and joint surfaces must not be violated by the transfixion pin, the use of intramedullary fixation is naturally limited to fractures of the shaft of the long bones at a sufficient distance from the extremity of the bone to insure adequate stability after insertion of the pin.

The possibilities of complications subsequent to insertion of intramedullary pins are those attendant upon the open reduction of any fracture. Obviously, aseptic technic must be scrupulously maintained. A high incidence of infection would more than outweigh the advantages. Because of the grave probability of infection, Häbler and Böhler employed blind nailing and advised against opening the fracture site when possible. This is not considered a valid reason. With the use of proper surgical technic and antibiotics, infection should assume a relatively minor role.

Approximately twenty years ago intramedullary bone grafts were tried at this clinic as a means of producing union in ununited fractures. The method rapidly fell into disrepute. It was a common observation in the roentgenograms of these cases that intense exuberant periosteal callus developed which was of poor form and quality, whereas endosteal callus formation or union at the junction of the cortices of the opposed fragments might or might not take place. In other words, intramedullary bone grafts apparently had an adverse effect upon the type, quality and location of the callus. Whether intramedullary pins will be a deterrent to union remains to be proved or disproved. Böhler states that callus formation is definitely disturbed by the presence of this foreign body in that the time of final maturity or consolidation is always longer with it than without it in the intramedullary canal. Even with the most rigid fixation from the intramedullary pin if the extremity is mobilized early, there is slight motion of the two surfaces at the fracture site which stimulates the formation of abundant periosteal callus but retards union of opposing cortices. In some cases of fracture of the humerus, which are treated by a hanging cast, this same

phenomenon is observed. Because endosteal callus formation is retarded by the nail, Böhler has even observed secondary nonunion when the intramedullary pin was extracted too early. In general however he feels that, since both fragments remain in good contact, the eventual union is much better than following *other forms of therapy particularly where traction appliances* are utilized, and too often the fragments do not remain in close contact. Certainly, intramedullary fixation will be no substitute for union. It has been our observation that if union does not take place any form of metallic fixation will eventually bend, break, or pull out of the bone.

We propose the following hypothesis to explain the reactions at the fracture site, namely excessive periosteal callus, minimal callus at point of contact of the fragments, minimal endosteal callus, and irregular areas of absorption of the ends of the fragments. The intramedullary pins, particularly if tightly fitting undoubtedly destroy endosteal bone from pressure and interfere with the blood supply of the inner two-thirds of the cortex. The larger the diameter of the intramedullary pin in proportion to the intramedullary canal, the greater the likelihood of necrosis. The smaller the pin, the less the periosteal callus; *the larger the pin the more the periosteal callus. Regardless of the size of the* intramedullary pin if an extremity is mobilized early lateral stresses and strains at the fracture site press the intramedullary pin against one side of the cortex more than the other. These areas, being thereafter devoid of blood supply from the pressure, account for the irregularity in the type of absorption of the ends of the fragment, the constant shearing force, vibration, and tendency toward angulation at the fracture site from mobilization exaggerates the amount of necrosis in a local portion of the cortex and endosteum. These forces may not always interfere with the outer portion of the cortex which is supplied by *periosteal blood supply. In the pressure areas, the periosteal callus* is laid down in abundance, in reaction to the partial or incomplete necrosis of the endosteum and the inner portion of the cortex, in much the same manner as the involucrum responds to a sequestrum in osteomyelitis. The periosteal callus is probably not a reaction per se to a foreign body but it is a secondary effect of pressure necrosis of the bone. Knowledge of the physiology and physiologic chemistry of fracture healing will have to be more extensive before all of these phenomena can be adequately explained.

In some cases, the bridging of the fracture site by periosteal bone, rather *than complete end-to-end union of the cortices of the fragments by endosteal* callus, assumes practical importance from the fact that intramedullary pins must be left in situ for a sufficiently long period to permit consolidation and maturity of the callus otherwise the fracture is likely to recur. This is particularly true in the lower extremity.

The question of interference with the hemopoietic structure of the bone marrow is of academic interest but of little practical importance otherwise, amputations would not be feasible procedures. The possibility of fat emboli, however presents a problem of considerable importance. To the present time, *several authors have reported the development of fat* emboli following the use of intramedullary pins. Whether this constitutes a real objection to the use of intramedullary pins can only be established with further experience. In animal experiments, Maatz showed that fat emboli could be demonstrated rou

tinely in the lungs after intramedullary pinning the fat emboli were not manifested clinically, however, when he nailed as many as four long bones in the same animal Böhler states that the clinical manifestations of a fat embolus have presented themselves in relatively few cases. In 700 cases of intramedullary pinning reviewed by Hübler, autopsies of seven patients revealed distinct microscopic evidence of fat emboli in two of the seven the embolism was massive and definitely contributed to the fatal outcome These deaths all followed repeated and unduly traumatic and shocking closed manipulations, principally of the femur

It is probable that trauma, incident to the introduction of an intramedullary nail, opens up venous spaces, allowing the entrance of fat droplets into the blood stream A pin which is sufficiently large to obliterate the intramedullary space acts as a piston in the canal, the pressure increases as the nail is driven into the distal end of a bone. A smaller intramedullary pin with a less stable fixation is probably preferable

There are also certain mechanical disadvantages to the use of the intramedullary pin which cannot be lightly dismissed, namely, bending breaking or migration of the pin, extraction of the pin under these circumstances, particularly in the femur, can be quite a major undertaking

General Principles of Intramedullary Fixation

In Europe, intramedullary nails are as a rule, inserted by a blind type of nailing under roentgenographic control. The ends of the fragments are apposed in proper position and alignment by a closed procedure A guide pin is then inserted through a small incision at one extremity of the bone and passed across the fracture site The position of the pin is verified by roentgenograms. Thereafter the intramedullary pin is introduced. Many rather cumbersome forms of apparatus have been designed to maintain position during this process.

In view of our experiences with 50 cases of intramedullary pinning, we see no reason for blind nailing In many fractures, particularly spiral or comminuted fractures, proper reduction and maintenance of the fracture for a sufficiently long time to insert the guide pin across the fracture site is extremely difficult. An undue number of manipulations are necessary thus contributing to the shock of the procedure. Successive roentgenograms must be made which subjects the patient and the surgeon if he uses fluoroscopy to an excessive amount of roentgen exposure Blind nailing obviously requires considerably more prolonged anesthesia than the introduction of the pin across the fracture site under direct vision For intramedullary pinning the exposure of the fracture site may be relatively small. The exposure is only sufficient to bring the fracture site into view and to permit the ends of the bone to be grasped with bone-holding forceps. When the pin is introduced in a retrograde fashion the incision must be sufficiently large to allow one fragment to be brought up out of the wound Even so only a small amount of soft tissue dissection is necessary Extensive stripping of the periosteum is unnecessary As a routine practice, we have found this open method more satisfactory than blind nailing The procedure can be carried out more rapidly than the average open reduction wherein screws and plates are applied.

Various types and designs of pins have been utilized for intramedullary fixation. The Küntscher pin for the tibia, ulna, humerus, and radius are simple V or U-shaped rods made of stainless steel, those for the tibia and radius being slightly curved and flexible. The Küntscher pin for the femur *is an incomplete* tube, more or less triangular in cross section, which is creased longitudinally to increase its strength against lateral stresses and strains For the forearm, we have used simple Kirschner wires or rods of slightly larger caliber Hansen and Street have utilized a diamond shaped solid steel rod for femoral fixations.

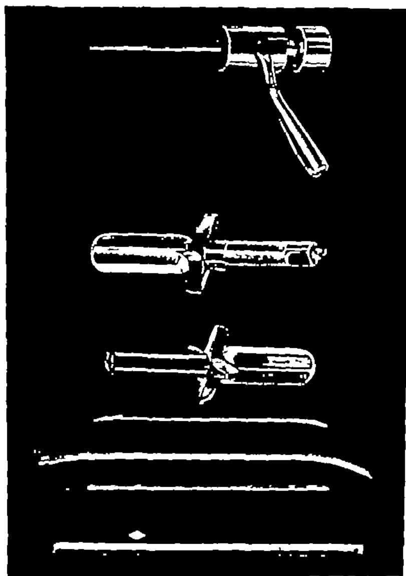


Fig. 274.—Instruments for extraction and insertion of intramedullary pins. The Kuntscher pins in order are for radius, tibia, and ulna Hansen-Street diamond-shaped pin is for femur (Courtesy of Richards Manufacturing Company Memphis, Tenn.)

For the femur and ulna rods or pins are satisfactory Since the pins may be introduced directly into the intramedullary canal in a straight line, the femur and ulna lend themselves readily to intramedullary fixation. The retrograde method of insertion, particularly in the ulna is a relatively simple procedure. Insertion into the tibia and radius is more difficult in that the pin must be introduced at a relatively flat angle, rather than directly into and in a straight line with the intramedullary canal.

The indications and contraindications as applied to each long bone will be given in a subsequent section of this chapter On the whole, fractures treated by intramedullary fixation must be a sufficiently long distance from the extremity of the bone to insure adequate fixation by the pin Stability is obviously better in transverse or short oblique fractures of the middle third of the shaft of a long bone. The presence of comminution does not contraindicate the procedure however, nor a large segmental or so-called third fragment fracture. In fact, in this latter group the method appears to offer far more advantages than any other form of fixation, the three fragments being literally strung on the intramedullary pin like beads on a string The method is applicable to a limited group of compound fractures i.e., those wherein the wound may be closed tightly and primary healing may be anticipated (p 374)

Before intramedullary pinning is undertaken Küntscher pins of a wide variety of sizes and lengths must be available In forearm fractures, if simple, round, flexible rods are chosen these can be used in maximum lengths and nipped off to the desired length during the operation. Proper instruments must be available, not only for the insertion of the pins and rods but especially for their extraction

Most of the errors in technic may be avoided by careful study preoperatively to determine the proper length and diameter of the pin. The use of pins which are too short or too long is a common error If the diameter of the pin is too large the cortex may be split If the point of a pin engages the cortex or meets undue resistance, the pin is best withdrawn and reinserted in a slightly different direction rather than forced, with the risk of fracture of the shaft, or, a pin of smaller caliber may be utilized. If the pin is driven forcibly into the cortex, extraction may be difficult, even with a well designed, strong and complete set of extraction instruments Postoperative roentgenograms should always be made prior to closure of any wound In two cases of fracture of the ulna, wherein a Kirschner wire was employed for fixation the wire met little resistance and protruded through the distal end of the ulna.

Soeur feels that as a rule, roentgenograms are unnecessary for making calculations for length. For the femur the distance is measured on the sound side from the top of the trochanter to the knee joint. A constant four centimeters is deducted from this figure. Any discrepancy in length of the pin selected for the femur may be compensated for by allowing a slight amount of the pin to project above the trochanter For the tibia, the measurement is made from the tip of the internal malleolus to the knee joint. From this is deducted four centimeters, or three centimeters if the fracture is situated in the distal third of the tibia. For the humerus, the measurement is made from the tip of the acromion to the olecranon, with the elbow flexed to 90 degrees. From this length five centimeters is deducted.

After union has been unquestionably demonstrated (this will be longer following intramedullary fixation than by the usual closed methods), the intramedullary pin should be removed. If the pin is not bent, extraction ordinarily will be relatively simple sufficient necrosis takes place around the pin to make it fairly loose in the canal.

Our experience with intramedullary pinning has been limited to fresh fractures Its use however has been recommended as a means of fixation in

leg-shortening operations for pathologic fractures secondary to metastatic or benign tumors, and for fixation following operations for malunion and non union.

FRACTURES IN CHILDREN

Fractures of the shaft of long bones in children seldom require open reduction Growth of bone in proportion to the age of the patient will compensate for errors in apposition and to a degree, for malalignment, and even for shortening Fractures of the femur particularly, may stimulate an overgrowth of the extremity In babies, fractures of the shaft of the humerus and femur are relatively common most of these are followed by normal growth, regardless of the alignment and position of the fragments. The degree of compensation obviously *decreases as the patient approaches adolescence.*

Bisgard, in a study of fractures of the long bones in children, observed that, in children 20 per cent of fractures involve an epiphyseal cartilage. Further fractures complicated by infection, open operation, or excessive trauma from manipulation are more likely to be followed by growth disturbances. Since the deformity is secondary to growth, several months or even a year may elapse before any material degree of deformity may be detected clinically This deformity will usually progress until the end of the normal growth period deformities will recur even after osteotomy until growth of the individual ceases. In addition to shortening there will be a deviation deformity of the extremity unless growth ceases simultaneously throughout the entire epiphysis. Bisgard estimates that, *in 2 5 per cent of fractures involving an epiphyseal cartilage,* the residual deformity secondary to disturbance in growth, will be of some clinical significance

In order to minimize growth disturbances in fractures involving epiphyseal cartilage the anatomic position of the fragments should be restored as nearly as possible The vast majority of these are best treated by closed methods. The most common exception to this rule are fractures about the elbow in children. Here vascular disturbances or growth disturbances will develop from poor position open reduction, often with internal fixation, will be necessary because the fragment cannot be reduced or cannot be maintained by external fixation. The indications for open operation for fractures of the elbow in children are described in detail on pp 476 489

COMPOUND FRACTURES

As previously stated the object of treatment of fractures is the establishment of union in good position, and the restoration of maximum function to the injured parts. In the accomplishment of this purpose in compound fractures, the treatment of the wound and the prevention of pyogenic and clostridial infection assumes primary importance The object of emergency treatment is the conversion of a contaminated wound to a clean wound, thereby promoting early healing of the soft tissues, and the conversion of a potentially infected open fracture to a healed closed one. Treatment of the fractured bone is secondary to the *prevention of infection.*

The first consideration is the patient s general condition. Emergency measures (Chapter I) are frequently necessary to combat pain hemorrhage and

shock, thereafter, attention is directed to the local condition From the time of injury until the patient is ready for the local preparation, the wound should be protected by a dressing and the extremity splinted

In taking the history, one should note how, when, and where the injury occurred, in the examination, one should determine the extent and type of soft tissue wound, the existence of any vascular or neurologic damage, and should have roentgenograms made to show the extent and type of injury to the bone In many cases, the true extent of soft tissue damage cannot be ascertained until surgical exploration is possible. Time, and the type and extent of soft tissue damage are two factors which have a direct bearing on the method of treatment.

Surgery should be carried out as soon as the patient's general condition will permit. Compound fractures are emergencies. With the passage of time, the probability of infection increases rapidly An elapse of twelve hours is usually considered the limit between a contaminated and an infected wound The time limit is less in more extensive and severe wounds. In order to provide some yardstick to parallel the time rule, wounds may be classified as follows

Type 1—Small puncture wounds caused by a protrusion of bone from within out, or by a bullet passing from without in, i.e., minimum damage to soft tissue.

Type 2.—Wounds extensive in length and breadth, but with little or no avascular, or devitalized soft tissues and relatively little foreign material.

Type 3—Wounds of moderate or massive size, with considerable necrosis of the soft tissues. The presence of foreign material increases the degree of severity

It should be noted that the differentiation of wounds in the three types is based principally on the amount of avascular or devitalized tissue

A proper evaluation of the wound, the time factor and the efficiency of the debridement will determine the extent of bone surgery the feasibility and extent of internal fixation, and whether primary closure or drainage of the wound is preferable.

The following treatment is based upon the premise that conditions for treatment are ideal i e. that adequate splinting will be utilized to minimize the trauma of transportation that patients will ordinarily arrive within twelve hours after the injury at a hospital equipped to provide adequate emergency treatment that surgery will be effectually carried out, and that constant observation by a well trained personnel can be assured during the postoperative period

Local Preparation.—The area surrounding the wound is thoroughly cleansed with green soap and water the wound remaining covered with a sterile dressing With a sterile razor the field is then shaved and the skin cleansed with benzine and ether To prevent further contamination all solutions must be applied in an ever widening circle from the edges of the wound The wound is thoroughly irrigated with copious quantities of saline solution During irrigation, all portions of the wound including the ends of the fragments are exposed and gently massaged to remove as much extraneous material as possible Mechanical washing of the wound is of far more importance in the prevention of sepsis than the application of antiseptic solutions in fact, the majority of anti

septic solutions irritate the tissues and do actual harm. After application of the routine operating room antiseptics to the skin around the wound, the field is draped

Treatment of the Soft Tissues.—For small puncture wounds induced by indirect violence, the preliminary cleansing is usually sufficient. The serrated borders of the skin are excised, and the wound loosely closed Probing in the wound, and the injection of antiseptic solutions are contraindicated, since these measures induce additional organisms into the wound and disseminate those already present. If a fragment of bone protrudes from the skin the end is cleansed with ether and washed with saline solution. In such cases, the wound must frequently be enlarged to permit reduction of the fracture The wound may also be enlarged to permit the use of internal fixation, if this is indicated.

Debridement is a term rather loosely applied in the American literature to cover the following procedure *exploration* of the wound, excision of devitalized tissue, eradication and elimination of foreign material, repair of damaged structures This procedure is applicable to the wound of type 2 and type 3 compound fractures, and must be carried out systematically and thoroughly The superficial wound must be extended sufficiently for complete exposure of all of the involved deeper structures. On the other hand, dissection should be limited to the minimum requirements to prevent dissemination of the contamination and an unnecessary addition to pre-existing trauma. Beginning superficially with the skin excision of devitalized structures should proceed layer by layer to the depths of the wound, with due regard for essential anatomic structures, such as vessels, nerves, and tendons. The skin should be excised sparingly keeping in mind the possibility of closure. All foreign material must be eradicated either by washing and lavage, or by excision of the adjacent tissue to which it clings.

Lacerations of tendons or nerves are repaired efficiently, but with less detail and precision than is observed in selective operative procedures. The necessity for care in handling of the soft tissues cannot be over-emphasized however, as necrosis incident to excessive trauma provides an excellent medium for growth of bacteria. A minimal amount of catgut should be introduced into the wound As a final step in the handling of the soft tissues, the wound is again thoroughly washed with copious quantities of saline solution

Antibiotics are not a substitute for careful debridement. Hampton's observations of battle casualties support this view He observed that penicillin will protect living tissue against the invasion of infection that penicillin will not sterilize devitalized infected tissue which inadvisedly or of necessity remains in the wound that it will not prevent septic decomposition of a contaminated hematoma, nor will it neutralize locally necrotizing enzymes in undrained parts. Wounds which are free of devitalized tissue, foreign material, and large hematomas are likely to heal without sepsis.

Treatment of the Bones.—The principles of proper handling of the periosteum and bones in selective surgical cases are outlined in the first of this chapter Their application is even more important in compound fractures. Loose particles of bone are left in situ, as large defects between the fragments impair the progress of union. Small particles with their periosteum and soft tissue attachments intact may even act as small grafts and may possibly stimulate os

teogenesis. Fragments of bone filled with foreign material, grease, or dirt, which cannot be thoroughly cleansed provide an exception to this rule Small fragments are removed in toto the ends of the larger fragments are excised to clean bone

The fracture must be reduced and immobilized The method whereby this is accomplished will depend upon the bone involved, the type of the fracture, the efficiency of the debridement, and the patient's general condition If it seems desirable to limit the trauma from surgery to a minimum, and the fracture is transverse, reduction may be accomplished manually, and a cast applied as for a closed fracture the cast is then bivalved to allow inspection of the extremity Compound fractures of the shaft of the humerus may be temporarily immobilized on an abduction humerus splint, to be followed by a hanging cast.

For the femur skeletal traction with the extremity supported in a splint is often advantageous in maintaining proper alignment of the fracture, while providing for inspection of the wound Before inserting the wires, the operator should change his gown and gloves, and completely redrape the field

After the introduction of the sulfa drugs, and particularly the antibiotics, we advocated the use of metallic internal fixation in compound fractures, based upon essentially the same indications as observed in closed fractures, provided primary healing might reasonably be expected following closure of the wound The use of metallic internal fixation is by no means a routine procedure in a relatively large series of cases however the number of infections has been no larger than previously reductions have been relatively anatomic, and in the majority union has taken place at practically the same rate as in selective surgical cases. If infection or sepsis develops and external fixation must be partially removed to permit inspection and dressing of the wound, internal fixation maintains the reduction Though drainage may persist and union progress slowly because of infection one troublesome factor in the management of these cases is eliminated. In utilizing metallic internal fixation, one must be cognizant of its disadvantages in the majority of cases, additional trauma will be created by exposure and stripping incident to the application of the fixation material. Regardless of how inert it may be the metal must be considered a material foreign to the normal anatomic structures. If sepsis ensues, draining sinuses will probably continue until the metal is removed The use of internal fixation under unfavorable conditions is likely to lead to undesirable sequelae.

In compound comminuted fractures of the lower third of the tibia, with a fracture of the fibula at the same level, the plate and screws may be applied through a separate incision to the fibula, with care to prevent contamination from the compound wound. In fractures of both bones of the forearm the same principle may be applied, i e. stabilization of one bone may obviate the necessity of metallic fixation of the other fracture through a more contaminated wound

Primary or Secondary Closure, Closed Plaster Method.—With the completion of debridement and reduction of the fracture, the question immediately arises as to the advisability of closing the wound, i.e., whether or not partial closure with drainage should be instituted, or whether the wound should be left completely open and early healing prevented by the use of petrolatum gauze. Although no rule can be rigidly applied, the following suggestions are offered In type 1 and type 2 wounds of less than twelve hours' duration, the wound

is usually loosely sutured with silk and drains are omitted. The same procedure is applicable to a few of the less severe type 3 wounds. As so aptly put by Hampton, complete closure of the wound is justified only when the "pabulum of wound sepsis is nil." As an added safety factor, in the more severe injuries, drainage may be established by a cigarette drain or petrolatum gauze, either in the most dependent portion of the wound or through counter incisions. When the wound is of more than twelve hours' duration, or the soft tissues are so extensively damaged that devitalized tissue must, of necessity, be left in the wound, continuous drainage from the depths of the wound should be insured with petrolatum gauze. As a rule, type 3 wounds, or those of more than twelve hours duration, should not be closed.

If surgical judgment dictates that there is some doubt about the feasibility of closing the wound, it is better to follow a conservative course by allowing unimpeded drainage from an open wound. Statistics from battle casualties of World War II have conclusively proved that with the use of antibiotics, secondary closure of open wounds on the tenth to fourteenth day is practicable. Secondary healing of the wound should take place in 80 per cent of properly selected cases. By this method, the hazards of a continuously draining open wound, namely, sequestration of exposed bone cortex, sloughing of tendons, muscle, and fascia, reinfection of the wound with a mixed bacterial flora at dressings, and prolonged healing of the wound attended by excessive scar formation, are obviated. In doubtful wounds, continuous drainage should provide a tremendous safety factor against pyogenic or clostridial infection. If the wound is clinically clean after ten to fourteen days, secondary closure may be instituted.

In civilian practice, the closed plaster method of treating compound fractures has a limited application, namely, severe type 3 wounds, usually of the hip and upper third of the thigh or shoulder. Shotgun wounds are notorious examples of this group. Because of the excessive amount of foreign material in the wound, the anatomic restrictions imposed upon surgery, and the excessive damage to the soft tissue structures, some degree of sloughing and sepsis is inevitable. Even without infection, the natural reparative and absorptive powers would hardly be able to cope with the foreign material and the devitalized soft tissue. This type of injury also presents a fertile field for anaerobic infection. In these cases, continuous drainage must ordinarily be maintained for a period of weeks or months.

After Treatment.—The extremity must be thoroughly immobilized to insure rest for the injured tissues. Edema is minimized by elevation of the extremity and the provision of dependent drainage. A removable pressure dressing also facilitates the healing of the wound. Constant observation should be maintained that any disturbances or impairment in circulation or the onset of pyogenic or gas infection may be promptly discovered.

Mixed antigas and antitetanus sera are routinely administered. As a precaution against anaphylactic reactions prior to injection, a small amount of the antitoxin should be introduced intradermally to determine whether the patient is sensitive to the sera. The value of prophylactic roentgen therapy or antigas serum is questionable. In massive type 3 wounds, the administration of a second dose of antitetanus serum after ten days may be advisable.

Penicillin is invariably administered in rather massive doses (p 16) until all danger of sepsis has passed For the reasons stated above penicillin alone is not insurance against a pyogenic or gas infection In combination with good surgery and surgical judgment however penicillin provides a tremendous safety factor in the prevention of stormy inflammatory processes.

Treatment of Gas Gangrene

In ordinary civilian practice gas gangrene develops so seldom that a sufficiently large number of cases have not been collected to provide any authoritative data as to its treatment Usually ideas regarding treatment are based on general impressions gleaned from a small series of cases We find that our former ideas were erroneous An analysis of 139 cases of gas gangrene by the War Wounded Committee of the Medical Research Council, of England, was reported by M G MacFarlane. Anyone particularly interested in this subject may well read this report as well as another by Jeffrey and Thomson In many previous reports, the seriousness of gas gangrene has been obscured by the inclusion of mild anaerobic cellulitis, saprophytic infection, or lesser clostridial infection In the above reports, only true cases of gas gangrene in the full sense of the word, were included, namely cases wherein extreme toxemia with all the classical signs and symptoms of gas gangrene were exhibited.

These studies have established certain fundamental principles of treatment i.e the early and combined use of appropriate surgery effective antibiotic therapy and polyvalent antitoxin All three measures are essential, and the omission of either surgery or antitoxin has an adverse effect upon the end result.

In patients with gas gangrene who did not receive a composite treatment the mortality rate was 87 per cent. Of those who received adequate treatment early the mortality rate was 45 per cent. The percentage of deaths in this series was materially higher in cases of gas gangrene involving the thigh, buttock or abdomen than those limited to the distal portion of the extremities

Antitoxin.—To be effective, gas gangrene antitoxin must be administered intravenously in adequate dosage (50 000 units) and as soon after the diagnosis as possible. (The division of the polyvalent serum used by the British was as follows 7 500 units of *Cl. welchii*, 3 750 units of *Cl septicum* antitoxin, 2,500 units of *Cl oedematiens* antitoxin.) The antitoxin should be administered preoperatively or during the course of the operation Thereafter additional doses of antitoxin are administered if the patient s toxic condition does not improve

MacFarlane s statistics show rather conclusively that, to be effective, the antitoxin must be given early The administration of antitoxin as a last hope of saving life was almost universally ineffectual since the damage by toxin was already irreparable. The delay in rapid neutralization of the toxin is not compensated for by an enormous dosage of antitoxin at a late date.

Surgery—The mortality rate of patients who received no major surgical treatment was practically 100 per cent. On the other hand, the rapid elimination of the whole site of infection was not in itself sufficient treatment in toxic cases. Unless the gangrene was limited to one group of muscles, such as the anterior tibial group or the adductor group amputation was commonly employed Amputation was generally performed as much for removal of a useless

limb as for the eradication of a primary focus. The anatomic restrictions imposed on surgery for gangrene in the region of the thigh, hip and abdomen were reflected in the mortality rate

Antibiotics—Jeffrey and Thomson believe that penicillin adds considerably to the other two requisites of the treatment surgery and antisera. Penicillin has a definite inhibiting effect upon spread of the disease if the amputation *does not eradicate all of the original focus*, or if amputation cannot be performed well proximal to the gangrenous area.

Altemeier and Furste recommend 1,000 000 units of penicillin every three *hours if the infection is established. In a recent case with a gas infection that* extended over the chest, we administered 500 000 units intravenously every hour for 5 doses Subsequently intramuscular administration brought the total to 8 000 000 units in the first twenty four hours and 12,000 000 units in forty-eight hours the patient survived with no apparent harmful effects from the large doses of penicillin

Our experience with gas gangrene has impressed us with the seriousness of this type of infection Heroic measures are more than justified. The careful analyses of MacFarlane, Altemeier and Furste, and Jeffrey and Thomson present convincing evidence of the necessity for a combination of surgery antitoxin, and antibiotics.

SURGICAL TREATMENT OF FRACTURES

METATARSAL BONES

Surgery for fractures of the metatarsal bones is indicated when displacement is so extreme that manual reduction is not feasible or maintenance of reduction is impossible. Usually the fragments are grossly displaced only if several of the metatarsal bones are fractured

Fractures of the metatarsal bones lend themselves well to intramedullary fixation. *Because of the small diameter of these bones, plates or screws* are not applicable Fixation by wire loops is relatively unstable. Heretofore, intramedullary fixation by the use of a small autogenous or homogenous bone peg was quite satisfactory Intramedullary wire fixation however is simpler and the prospect of union seems to be equally as good There are few fractures near the bases or proximal ends of the metatarsal bones which cannot be treated adequately by conservative measures. An isolated fracture of the midportion of a shaft, particularly if the adjoining metatarsal bones are intact, *usually* will cause little difficulty The more distal the fracture, the more definite is the indication for open reduction. Fractures through the metatarsal just proximal to the head are difficult to hold in proper position by conservative measures. With intramedullary fixation, the position may be easily maintained. The type of intramedullary fixation to be described has one fundamental disadvantage the end of the wire is left protruding through the skin for a period of three weeks, and the wire crosses the articular surface of the head of the metatarsal bone. Since the wire is left intact only for a period of three weeks, we have had no complications from infection, and no stiffness or rigidity of the metatarsophalangeal joints. We recognize these two factors, however as definite objections to the method.

Technic.—The metatarsal fractures are exposed through an appropriate incision The incision should be relatively small Dissection of the soft tissues is limited to a minimum The proximal end of the distal fragment is lifted out of the wound and with the toes in dorsiflexion, the pointed end of a small Kirschner wire is drilled into the intramedullary portion of the distal fragment, the wire being drilled distally until its point emerges from the skin The drill is then removed from the wire and reversed The wire is withdrawn through the skin until the blunt end is level with the fracture site. The ends of the fragments are next apposed and the wire is drilled proximally, until the blunt end of the wire meets resistance at the base of the metatarsal bone One-fourth inch of the wire is left protruding through the skin This is dressed and sealed off with a collodion dressing

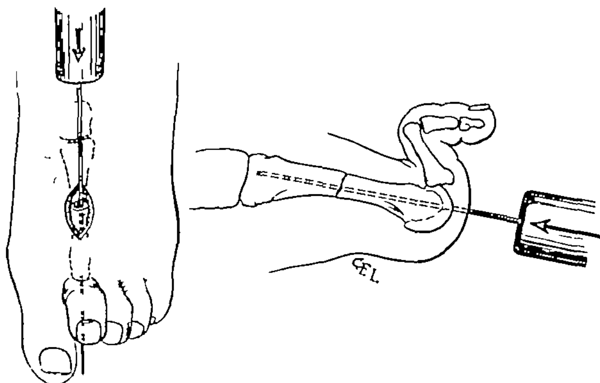


Fig. 271.—Retrograde insertion of intramedullary pin for fixation of metatarsal bone.

As an alternative to the above technic reduction may be maintained by inserting an especially prepared homogenous or autogenous bone peg (p 116) of appropriate size into the medullary cavity of the proximal fragment, and leaving a small protruding portion to be placed into the intramedullary cavity of the distal fragment as reduction is effected.

After Treatment.—The foot is immobilized in a cast from the tibial tubercle to the toes. Sufficient dressings are placed around the ends of the wires to prevent their coming in contact with the plaster The patient is kept in bed for a period of three weeks with the foot elevated At the end of this time the intramedullary pins are extracted and a walking boot cast is applied, the plaster being well molded to the transverse and longitudinal arches By the end of six to eight weeks postoperatively healing is sufficiently solid to permit walking in a stiff soled shoe, with an arch support and metatarsal pad.

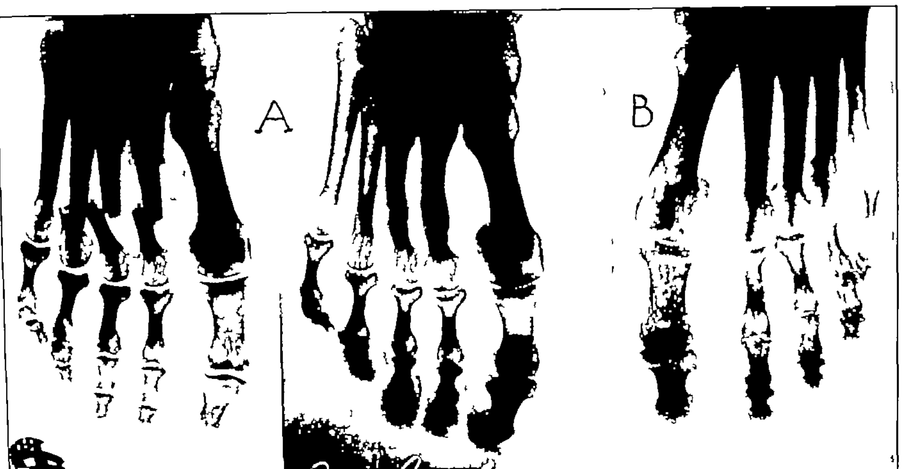


Fig. 376.—*A*, Fractures of shafts of metatarsal bones before, and three months after fixation by intramedullary bone pegs. *B*, Fractures adjacent to heads of metatarsal bones; fixation with intraosseous and intramedullary homogenous bone pegs.

TARSAL BONES

With the exception of the astragalus, open operation for reduction of fractures of the tarsal bones is seldom necessary unless the bones are also dislocated and cannot be reduced manually When surgery is required, usually replacement or excision of the fragments suffices If extensive comminution necessitates wide resection of bone from one side of the foot, a similar amount is removed from the opposite side to restore proper alignment.

FRACTURES OF THE ASTRAGALUS

Fractures of the astragalus present many problems peculiar to this bone The blood supply of the astragalus is analagous to that of the neck of the femur in that the astragalus receives the majority of its blood supply from a branch of the dorsalis pedis artery which enters the neck. McKeever observes that the circulation of the astragalus is not well understood. From injected specimens he demonstrated that the blood is carried into the astragalus in the dense astragaloscaphoid ligament, the latter extends from the dorsal surface of the neck of the astragalus to the dorsal periphery of the scaphoid. Other than the branches through the neck, McKeever could not demonstrate any other source of blood supply Following fracture of the neck of the astragalus proximal to these small vessels, the blood supply to the body of the astragalus is impaired or interrupted thus the body of the astragalus may be subjected to the hazards of aseptic necrosis following fractures or fracture-dislocations.

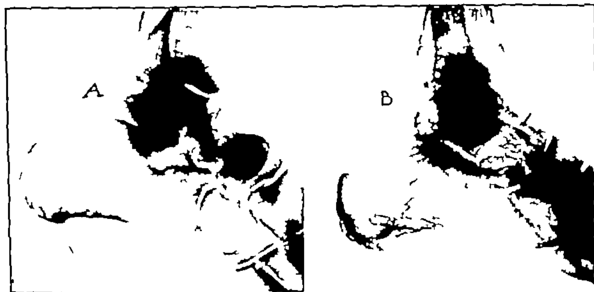


Fig. 177.—*A* Fracture through neck of astragalus with dislocation of astragaloscaphoid joint and subluxation of subastragalar joint. *B*, Solid union with viable fragments after open reduction and fixation with homogenous bone peg.

Any fracture which involves a joint is a difficult problem, and this is particularly true of a weight bearing joint As pointed out by Miller and Baker, the major portion of the surface of the astragalus is covered by articular cartilage For this reason practically any fracture of the astragalus will in one way or another involve a joint surface More weight per unit of area is borne by the superior surface of the astragalus than by any other bone in the body Consequently even though the viability of the body of the astragalus is maintained, there is a grave possibility of an eventual traumatic arthritis.

In fractures of the astragalus, accurate reduction is essential in order to re-establish the anatomic position of the various articular surfaces and facilitate revascularization of the body. Any irregularities which may persist in the joint surfaces produce arthritic changes upon motion and weight-bearing.

The following indications for treatment of fractures of the astragalus are based upon a study made by Boyd and Knight, of 58 patients who were treated at the Campbell Clinic up to 1942. Of these 58 fractures, 20 required only conservative treatment, namely minor fractures of the head neck and body including chip fractures and fractures of the posterior tubercle (Stieda's process).

Impacted fractures of the head usually associated with compression fractures of the scaphoid, respond satisfactorily to conservative measures. Because of the incongruity of the astragaloscaphoid joint, arthrodesis may eventually be necessary for relief of pain.

Incomplete fractures of the neck, or fractures of the distal portion of the neck without displacement, may well be treated conservatively. Fractures of the neck with displacement should be treated by open reduction and internal fixation. This is best accomplished by the insertion of a screw obliquely across the neck fragment into the body of the astragalus.

Fractures of the neck associated with even a minimal subluxation of the body of the astragalus require more formidable treatment. In the presence of dislocation of the body, the avascularity of the body of the astragalus is unquestionable. Attention is therefore directed toward the re-establishment of vascularity to the body of the astragalus. This is accomplished by removal of the articular surfaces of the subastragalar joint i.e. subastragalar arthrodesis. The neck is anatomically apposed to the body of the astragalus and fixed in place by a screw. Thus there are two routes whereby new capillaries may grow into the body of the astragalus, i.e. from the neck and from the os calcis.

Technic of Open Reduction.—The head and neck of the astragalus are exposed by an incision three inches in length, beginning above and just anterior to the internal malleolus, curving forward and downward toward the sole of the foot, and ending on the medial aspect of the body of the scaphoid. The anterior tibial tendon must not be incised. The fracture site, the anteromedial aspect of the neck and the body of the astragalus are exposed. Soft tissues about the head and neck of the astragalus should be preserved intact, so far as possible. Reduction is accomplished with little difficulty. Beginning just posterior to the articular surface of the head on the medial aspect of the neck, a hole is drilled obliquely, posteriorly and laterally through the neck and body. A screw of proper length is inserted into the hole and its final position is checked by roentgenograms.

In elderly individuals with a rather fragile cortex, or in relatively distal fractures, firm fixation cannot be secured by an obliquely placed screw the head of the astragalus is partially dislocated from the astragaloscaphoid joint. The screw is inserted in a longitudinal plane, directly through the articular surface of the head of the astragalus, and is countersunk below the level of the articular cartilage.

After Treatment.—The foot is held in the neutral position and the ankle immobilized in a cast extending from the knee to the toes. The cast should

be well molded into the arch of the foot After eight weeks, the extremity is placed in a walking boot cast and weight bearing is allowed Three months postoperatively, if union has progressed satisfactorily the cast is removed and an arch support and orthopedic shoe are fitted to be worn for an additional three months.

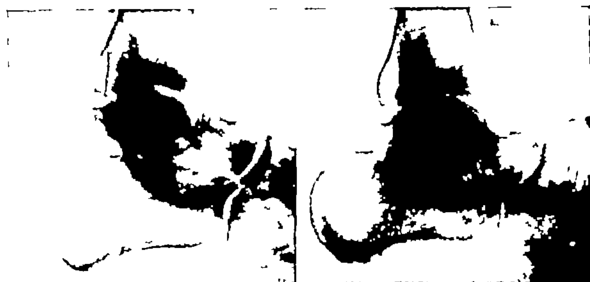


Fig [illegible].—Comminuted fracture of neck of astragalus with subluxation of subastragalar joint treated by subastragalar fusion and internal fixation.

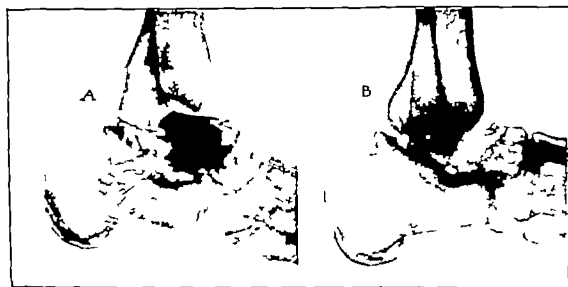


Fig. 270.—*A* Old comminuted compound fracture of body of astragalus. Remaining fragment an infected sequestrum. *B* After astragalectomy Infection precluded dissection necessary for complete backward displacement of foot.

Technic of Open Reduction and Subastragalar Fusion.—The operative field is exposed by an anterolateral incision (p 137) In fractures through the neck of the astragalus complete exposure of the subastragalar joint is accomplished with little difficulty With an osteotome, the articular surfaces of the subastragalar joint are removed and the cancellous surfaces of the astragalus and os calcis apposed with maximum contact. Additional cancellous bone may be obtained from the anterior end of the os calcis to fill any defect The head and

neck of the astragalus are then approximated to the body and fixation is accomplished through a medial incision as described above.

After Treatment.—(See p 384)

Fractures of the Body of the Astragalus

Simple fractures of the body of the astragalus without displacement, are treated by immobilization in plaster In some of these cases, sufficient traumatic arthritis of the subastragalar joint may develop later to necessitate fusion. Simple fractures of the body with displacement should be treated by open reduction, and by as nearly an anatomic replacement of the fragments as possible. When the posterior fragment is large and completely dislocated, and thus is deprived of its blood supply, reduction and internal fixation should be accompanied by a subastragalar fusion (pp 523 385 524)



Fig. 310.—Calcaneotibial fusion following comminuted fracture of body of astragalus.

Comminuted fractures of the body of the astragalus with gross displacement present the most difficult therapeutic problem. Accurate replacement of the fragments is impossible or impracticable. Removal of the astragalus is the only logical course The end results of astragalectomy in adults are usually poor because of pain on weight bearing instability and lack of endurance. The end results of calcaneotibial fusion are superior to those of astragalectomy as the foot is painless the stability is good, and sufficient compensatory motion usually develops in the midtarsal joints to enable the patient to walk with a fairly elastic gait and only a slight limp

Another possible treatment of this lesion is an immediate panastragalar arthrodesis Because of the avascularity of the body of the astragalus, however this is difficult to secure and to wait for revascularity to be followed by an arthrodesis unduly prolongs the convalescence and period of disability

Calcaneotibial Fusion.—The operative field is exposed through an anterolateral incision. The comminuted fragments of the body of the astragalus are removed. With gross comminution this is a relatively simple procedure. In comminuted fractures of the astragalus of several months' duration, or if the junction of the body and neck of the astragalus is intact, an osteotome is utilized to divide the astragalus into as many portions as necessary to facilitate removal. An osteotome is then driven through the proximal portion of the scaphoid bone, and the proximal segment of the scaphoid, together with the head and neck of the astragalus, is removed. The articular surfaces of the tibia and os calcis are next excised. The medial surface of the external malleolus is then scarified.



Fig. 281.—Ten years after fractures of the astragali. The astragalectomized foot has been a continual source of pain. Patient relies for major portion of weight bearing on opposite foot wherein a calcaneotibial fusion was performed.

The soft tissue attachments about both malleoli are now stripped sufficiently to allow backward displacement of the foot until the scaphoid bone will come in contact with the tibia. The soft tissues will collapse like an accordion and resist efforts to approximate the os calcis properly with the tibia. Thus it may be necessary to resect a portion of the internal and external malleoli. The tibia is denuded at the point of contact with the scaphoid bone. While the foot is held at a right angle to the leg a Steinmann pin is passed through the ventral surface of the foot, through the os calcis and upward into the intramedullary canal of the tibia. With a screw the scaphoid is fixed to the tibia. Excessive bone chips from the operation are denuded of their cartilage and packed about the junction of the os calcis scaphoid bone and the tibia.

After Treatment.—With the foot at a right angle to the leg and the knee flexed to 135 degrees, the extremity is immobilized by a cast from the groin to the toes. The Steinmann pin which protrudes from the bottom of the foot, is incorporated in the cast. A large window is cut in the cast to allow for swelling. At the end of four weeks, the cast is changed the Steinmann pin removed and immobilization is continued for another six weeks. If union appears to be solid after four weeks in a short walking cast, a brace with no joint at the ankle may be substituted. The ankle should be protected for at least eight to twelve months.

In view of the decrease in height, and stiffness and inelasticity of the ankle joint incident to calcaneotibial fusion, Blair has suggested a new approach to this problem The comminuted fragments of the body of the astragalus are removed and a *sliding graft is brought from the anterior surface of the tibia into the remnant of the head and neck, in an attempt to obtain fusion across this area* An insufficient number of cases has been reported from which to draw definite conclusions as to the practicability of this procedure. Blair points out the advantages of the method as follows the outward appearance of the foot is not changed backward displacement is not necessary, there is no

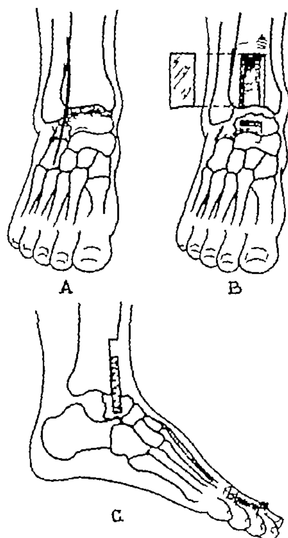


Fig 282.—Blair fusion operation for comminuted fractures and fracture-dislocations of body of astragalus *A* Line of skin incision *B* Sliding graft removed from distal anterior surface of tibia. Comminuted fragments excised. *C* Graft embedded in slot in neck of astragalus (From Blair H. C. Am. J Surg 59 37 1943)

shortening of the extremity the relationship of the foot and ankle remain more or less normal and the weight-bearing thrust is placed on more or less normal, undisturbed joint tissue. Further he states that there is no tendency toward the development of any lateral deformity of the foot on the leg Following this operation, there is still some slight flexion and extension of the foot on the leg the two subastragalar facets and the astragaloscaphoid joint allowing a rocking motion of greater or less degree.

Technic (Blair) —The ankle is exposed through an anterolateral incision (p 187) The fragments of the fractured astragalar body are removed

though the head and neck fragment is left undisturbed. A sliding graft one inch wide and two inches long is then removed from the anterior aspect of the tibia, and the cartilaginous tip on the end of the graft is removed. The graft is then introduced into a previously prepared hole in the neck of the astragalus. The hole is about three-fourths inch deep and is sufficiently large to admit the end of the graft With the ankle at 100 degrees' equinus, the upper end of the graft is fixed to the tibia. Cancellous chips of bone are packed about the distal end of the graft



Fig 282.—Ten years after Blair fusion. (Courtesy of Dr Harry Blair)

After Treatment.—A cast is applied from the groin to the toes, with the knee in extension. After ten to fifteen days, the cast is removed and a new non padded walking cast is applied The patient is encouraged to walk as soon as he is able to bear weight

OS CALCIS

The treatment of fractures of the os calcis is predicated upon the types of the fractures. For practical purposes, these may be classified as follows

Type I —Isolated or single fractures, located in the body or tuberosity, with little displacement, and without extension into the articular surfaces. The simple application of a plaster case, with early weight bearing is adequate, with one exception avulsion fractures of the tuberosity which include the attachment of the tendo achillis should be replaced and fixed with a Vitallium screw under direct vision Avulsion fractures of the tuberosity should not be confused with

the small triangular V fractures which take place at the posterior superior border of the os calcis, these do not include the attachment of the tendo achillis. The tendon is inserted into the os calcis at a lower level.

Type II —Linear, or comminuted fractures of the body or tuberosity of the os calcis with displacement of the fragments, but without extension into the articular surfaces of the subastragalar joint. In this group, manipulative reduction, with or without pin fixation, is necessary The disability however, is *usually not prolonged and the end result is relatively satisfactory*

Type III —Severe crushing injury to the os calcis, with impaction and displacement of the subastragalar articular surfaces. Usually the tuber angle of the os calcis is lost the body of the os calcis is shortened and broadened and portions of the articular surface may be deprived of blood supply leading to aseptic necrosis In this group there are two courses of procedure (a) early arthrodesis, as advocated by Conn and Harris, and (b) treatment by the Böhler Cotton, or other conservative measures, to be followed by late arthrodesis (p 523) if necessary We pursue the latter course

Harris observes that fractures through the joint surface, and aseptic necrosis in one or more of the fragments are so certain to produce permanent disability that these cases should be treated early by subastragalar fusion. Before undertaking fusion however *one should be certain that no varus deformity is present* The operation is carried out ten days after the primary reduction by Gallie s method (p 524) through a posterior window in the cast the transfixing wires are left intact. He uses a graft from the posterior surface of the tibia, just above the ankle joint. Following the most severely comminuted fractures of the os calcis *a painless, useful foot has been restored within a period of six months* by this procedure

J S Speed and Stewart have recently analyzed the fractures of the os calcis in this clinic. From these results they believe that most surgeons are unduly pessimistic regardless of the type of treatment given if the functional results are evaluated after four or five years, they are *surprisingly good. The majority* of patients are able to pursue any type of work. Many of those who had considerable residual deformity either obtained spontaneous subtalar fusion or had a relatively painless subtalar joint despite traumatic arthritis.

In view of the surprisingly good functional results which have been observed in patients who were treated conservatively and *followed over a period of five* years or longer it is difficult to formulate the indications for surgical fusion Neither the type of fracture nor the period of time during which disability is persistent following injury determines the exact indication for surgical fusion It would seem advisable that, so long as the functional capacity of the foot is improving and the patient can engage in reasonable *physical activities*, surgical fusion may be postponed indefinitely The indications for surgical fusion, even in late cases, is influenced materially by the patient s financial and psychologic condition. When the condition of the foot becomes static, the patient is definitely disabled, and is financially dependent, surgical fusion offers a positive and quick solution to the problem Certain *minor fractures involving* the articulation, with persistent astragalar pain and limited motion, also should be fused after careful study Many of these injuries are more disabling than would appear from the physical and roentgenologic examination.

FRACTURES OF THE ANKLE

In fractures of the ankle only the slightest variations from normal anatomy are compatible with good function of the joint. Post reduction roentgenograms should be studied with the following considerations in mind (a) whether the normal relations of the ankle mortise are restored, (b) whether the weight bearing alignment of the ankle is at a right angle to the longitudinal axis of the leg, and (c) whether the contours of the articular surface are as smooth and regular as possible Surgery is warranted if closed procedures have failed to satisfy these requisites and the desired end results may reasonably be expected by open reduction With a few exceptions, surgery will not be in order until conservative measures have been tried and have failed either to secure or maintain reduction

Bimalleolar, or Pott's Fracture

If bimalleolar fractures cannot be reduced satisfactorily the internal malleolus is usually the fragment which should be stabililized by internal fixation, thereafter the fibular fracture may be easily reduced by maneuvers against the stable and fixed internal malleolus. Conservative procedures fail most often when both malleoli are fractured transversely at the approximate level of the articular surface of the tibia.

Internal Fixation of the Medial Malleolus—*A longitudinal incision two inches in length is made over the medial aspect of the ankle joint If the incision is carelessly made, the sheath of the posterior tibial tendon will be opened unnecessarily or the tendon may even be lacerated.* Usually the distal fragment of the internal malleolus is in a forward or anterior position frequently, a small fold of periosteum is interposed between the fracture surfaces With a towel clip the detached malleolus is brought into normal position and maintained while a hole is drilled in a proximal and lateral direction into the metaphyseal region of the tibia Thereafter a screw of proper length is inserted. Roentgenograms should be made to verify the position of the screw and both malleolar fragments before the wound is closed.

Fractures of the internal malleolus associated with diastasis of the distal tibiofibular joint may require additional fixation by a screw placed transversely across the distal tibiofibular joint (p 343)

After Treatment.—(See p 394.)

Internal Fixation of the Lateral Malleolus.—The external malleolus and lower end of the fibula are exposed through an anterolateral longitudinal incision. The distal end of the external malleolus is exposed by splitting the fibers of the external lateral ligament of the ankle joint longitudinally With the foot in marked inversion a large Kirschner wire is introduced directly into the distal fragment, in line with the longitudinal axis of the intramedullary canal of the fibula. When the point of the guide wire emerges at the fracture site, the distal and proximal fragments are properly apposed and the pin is introduced for a distance of four inches up the proximal fragment The position of the fragments should be verified by roentgenograms. The excessive wire is

nipped off with a wirecutting instrument, one-fourth inch of the wire allowed to protrude. The protruding portion of the wire is then bent angle to prevent migration of the wire up the intramedullary canal, a facilitate its removal at a later date

After Treatment.—(See p 394.)

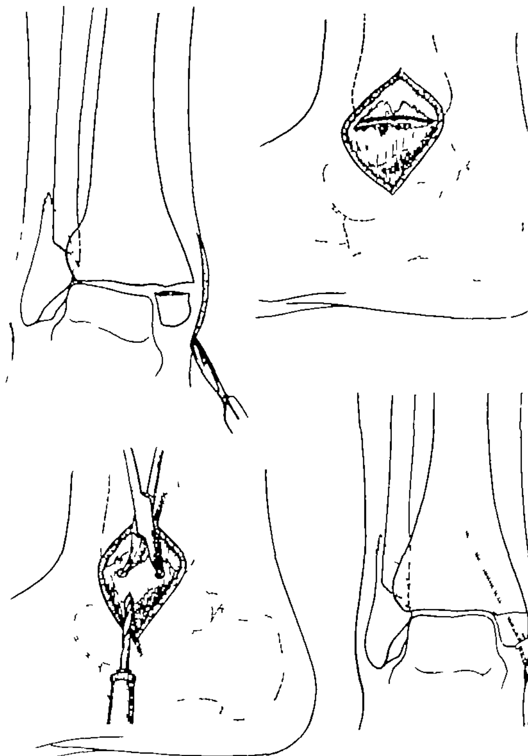


Fig. 284.—Bimalleolar fracture with lateral displacement and eversion of foot. Reg ment of internal malleolus and fixation with screw provides stable point for inversion of and ankle, to correct fracture of external malleolus.

Trimalleolar, or Cotton's, Fracture

In fractures about the ankle joint a larger number of trimalleolar (Cotton type) fractures will require open operation than any other In addition to the fractures of the internal malleolus and fibula, the posterior lip of the articular surface of the tibia is fractured and displaced allowing backward and lateral displacement and eversion of the foot occasionally the internal malleolus may be intact.

The indications for open reduction depend chiefly upon the size of the *posterior tibial fragment* If the posterior fragment consists of less than one third of the articular surface, reduction may ordinarily be accomplished and maintained Frequently the posterior fragment will remain in a slightly proximal position This is of no consequence if the anterior segment of the tibia is sufficiently large to provide a stable weight bearing surface and the astragalus can be maintained in proper relation with the anterior portion of the tibial articular surface Even a slight degree of posterior subluxation, however, is not acceptable



Fig. 185.—Cotton's fracture. The tibial fragment involves approximately one-half of articular surface held in anatomic position by one wire nail. Excellent functional result.

If the posterior fragment consists of one third or more of the articular surface, open reduction and internal fixation will usually be necessary otherwise, posterior subluxation is likely to recur The posterior and proximal displacement of the tibial fragment creates an offset, or step-cut arrangement at the fracture site. With the foot displaced posteriorly, this irregularity in the articular surface of the tibia is brought to bear upon the weight bearing surface of the astragalus, shaving and creasing it with motion and weight-bearing until sooner or later a severe traumatic arthritis develops.

Internal Fixation of Posterior Malleolus.—The skin and superficial fat are incised medial to the tendo achillis for a distance of three inches the tendon is retracted laterally and dissection continued in the midline down to the posterior capsule of the joint. The flexor hallucis longus tendon which traverses the

posterior capsule from without inward, is retracted medially. The normal articular relation between the astragalus and tibia is established by forward traction on the foot, followed by adduction and inversion. The upward displacement of the posterior lip of the tibia is then corrected by traction with a towel clip, and the correction maintained by the insertion of two rustless steel nails or a screw from below upward and forward through the fragment and shaft of the tibia. Thereafter satisfactory alignment of the external and internal malleoli can generally be effected by manual force. To insure proper relationship between all surfaces, roentgenograms are made while the patient is on the table. If restoration is unsatisfactory, further operative procedures may be employed as described above for bimalleolar fractures. An unstable internal malleolus is usually responsible. Rather than extend the posterior incision around to the internal malleolus, a separate small longitudinal incision should be utilized. Healing of the incision is more likely to take place primarily.

After Treatment.—With the knee in flexion and the foot in mild equinus and inversion, the extremity is immobilized in a cast from the mid thigh to the toes. To allow for postoperative swelling a window is cut in the cast over the dorsum of the foot and ankle. Roentgenograms are made immediately and again after the elapse of one week to verify the position of the fragments in the cast. Six weeks postoperatively a walking boot cast is applied and slight weight bearing permitted with the aid of crutches. Ten weeks after operation, if union has progressed satisfactorily an ankle brace, with an inner T strap to prevent eversion of the foot is fitted. An arch support of leather and cork, or steel, is also worn to insure further slight inversion of the foot. The brace should hold the joint rigid for one month before motion is allowed in the ankle, and should be worn thereafter for an additional three months. The use of the arch support should be continued for six months.

Fracture of the Anterior Margin of the Tibia at the Ankle Joint

Fractures of the anterior margin of the tibia present essentially the same problems as those of the posterior margin though in reverse. They differ however in one respect: fractures of the anterior margin usually are produced by a fall from a height, wherein the foot and ankle are forcibly dorsiflexed. As a consequence comminution, compression or crushing of the articular surface of the tibia is likely to be more severe. Thus, anatomic restoration of the articular surface of the tibia may not be possible. When necessary associated fractures of the internal malleolus are treated as described above.

Technic.—The fracture site is exposed through an anterolateral incision three to four inches in length (p. 137). The extensor tendons are retracted medially and dissection is continued until the entire anterior surface of the ankle joint is adequately exposed. Small, loose fragments of bone are removed, as much as possible of the articular surface intact being preserved. The anterior subluxation of the ankle having been reduced, the large anterior triangular fragment is apposed to the shaft of the tibia in anatomic position and transfixed with a screw.

After Treatment.—A boot cast is applied with the foot and ankle in the neutral position. Four weeks postoperatively a boot cast is applied and weight bearing begun. A brace with a rigid joint at the ankle is fitted eight weeks after operation, free motion being permitted four weeks later.

Explosion Fractures of the Ankle

Explosion fracture of the ankle usually is produced by a fall from a height and consists of a comminuted fracture of the ankle joint, as well as a fracture of the lower third of the tibia If comminution is excessive open reduc

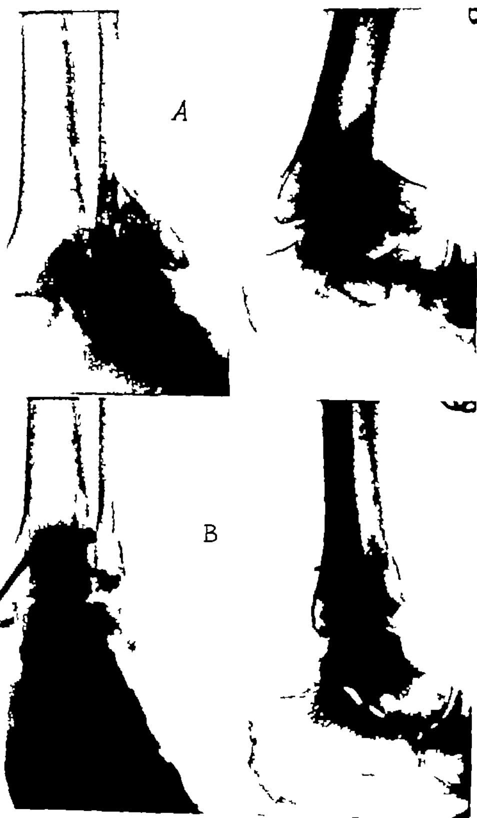


Fig 266 —*A* Comminuted fracture of anterior margin of ankle joint with fracture of internal malleolus. *B* After open reduction and internal fixation. Comminution is usually so extensive that a perfect anatomic restoration is impossible.

tion is impractical The small fragments resemble the pieces of a jigsaw puzzle, and although they may be assembled fairly well they are too small for transfixion with any type of fixation. The fragments are lined up as anatomically as possible by closed methods. Fusion of the ankle joint will probably be necessary later

Frequently the pattern as seen in the lateral view assumes a T-shape. If re-establishment of the continuity of the ankle joint is possible, open reduction is indicated. Reduction and fixation, as described previously for fractures of the ankle and for fractures of the shaft of the tibia, are applicable. Exposure of the entire fracture site is best obtained by an incision beginning on the anteromedial aspect of the tibia at the middle or lower third, and extending distally to a point just below the internal malleolus. Through this incision, usually the two main fragments of the tibial metaphysis may be apposed and transfixed and the internal malleolus or other small fragments may be reattached. If necessary, additional exposure of the ankle joint may be obtained by a short anterolateral incision.

Even though a fairly satisfactory anatomic reconstruction is accomplished, in many of these cases fusion will eventually be required because of severe contusion and bruising of the articular surfaces, and consequent degeneration and traumatic arthritis

SHAFT OF THE TIBIA

Fractures of the shaft of the tibia cannot be treated by any definite rule. All factors discussed in the introduction to this chapter must be considered in each case Closed methods are preferred in transverse fractures if they can be hooked in a stable position Many oblique fractures heal quite satisfactorily by conservative measures. However they must be observed regularly displacement and shortening may occur with a commensurately poor result. If maintenance of position is improbable oblique or spiral fractures are treated by open reduction and internal fixation in preference to skeletal traction or extra skeletal fixation Thereby anatomic reposition is assured, the period of hospitalization is minimized and the results are uniformly good If an oblique fracture is short, allowing only one transfixion screw fixation is improved by the addition of a plate If two or more screws can be placed across an oblique or spiral fracture, fixation is usually adequate Fractures with a single large butterfly fragment i e two long oblique surfaces, may be treated in a similar manner

The tibia lends itself less readily to intramedullary fixation than some of the other long bones one of the principal advantages is lost namely early mobilization. Fixation of a fractured tibia with an intramedullary pin is seldom firm enough to prevent rotational or torsional movements. Thus, some form of external fixation should augment the intramedullary pinning For the pin to extend sufficiently beyond the fracture site to produce stability the indication for this method must be limited to those fractures of the middle and upper thirds, the middle and lower thirds, or between these two limits. There is little reason for using the method for an ordinary long oblique or spiral type of fracture. These respond too well to transfixion with screws The desirability of intramedullary pinning of transverse fractures of the middle third may be

questioned. Usually, these may be treated successfully by conservative measures, or by fixation with a plate and screws. *In segmental or third segment fractures of the tibia, however, an intramedullary pin provides a more efficient form of fixation than any other. In this group, the use of plates and screws are notoriously attended by a relatively high percentage of nonunion particularly those of the distal segment. By use of the intramedullary pin, alignment and position may be maintained, yet the normal tonicity of the muscles will still telescope the fragments as absorption occurs.*

In fractures of the tibia of more than three or four weeks' duration, especially in the middle and lower thirds, open reduction and internal fixation must be supplemented by an osteogenic factor. This may be accomplished by the use of a routine onlay bone-graft procedure or if a metal plate and screws are utilized, cancellous bone from the ilium may be added.

Long Oblique or Spiral Fractures of the Tibia

Transfixion by Screws.—*An incision five inches in length is made just lateral to the crest of the tibia; the line of fracture is thus avoided.* Dissection is carried down to the crest and the periosteum is incised longitudinally. The anterior group of muscles is displaced from the lateral aspect of the tibia

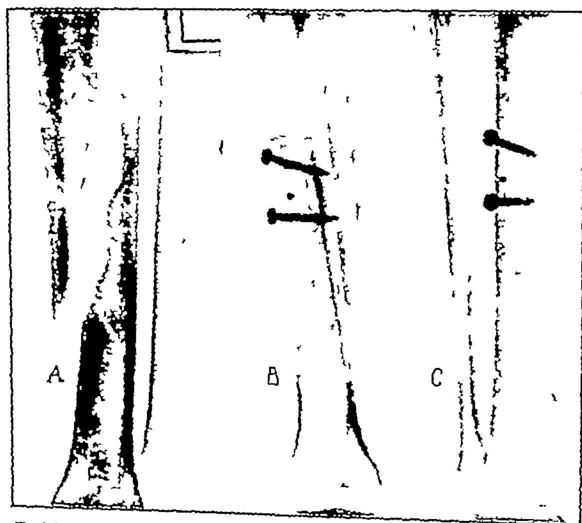


Fig. 317.—*A*. Long spiral fracture of tibia. *B* and *C*. Anatomic position maintained by two Vitallium screws.

tion is impractical. The small fragments resemble the pieces of a jigsaw puzzle, and although they may be assembled fairly well, they are too small for transfixion with any type of fixation. The fragments are lined up as anatomically as possible by closed methods Fusion of the ankle joint will probably be necessary later

Frequently the pattern as seen in the lateral view assumes a T-shape If re-establishment of the continuity of the ankle joint is possible, open reduction is indicated. Reduction and fixation, as described previously for fractures of the ankle and for fractures of the shaft of the tibia, are applicable Exposure of the entire fracture site is best obtained by an incision beginning on the anteromedial aspect of the tibia at the middle or lower third and extending distally to a point just below the internal malleolus. Through this incision usually the two main fragments of the tibial metaphysis may be apposed and transfixed and the internal malleolus or other small fragments may be reattached. If necessary additional exposure of the ankle joint may be obtained by a short anterolateral incision.

Even though a fairly satisfactory anatomic reconstruction is accomplished, in many of these cases fusion will eventually be required because of severe contusion and bruising of the articular surfaces, and consequent degeneration and traumatic arthritis

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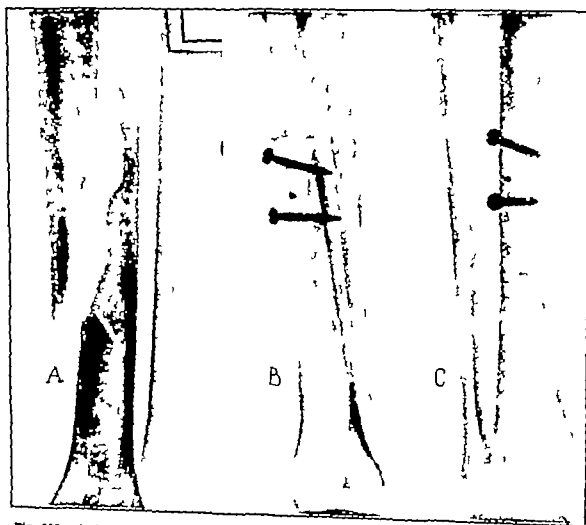


Fig. 287 —A Long spiral fracture of tibia. B and C Anatomic position maintained by two Vitallium screws.

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fragment and proximal fragments are then aligned with each other and with the plate and screws are inserted into the distal fragment

After Treatment.—(See p 398)

Segmental, Comminuted, or Third Fragment Fractures

For these fractures, intramedullary pins provide efficient fixation For the tibia Küntscher intramedullary pins should be available in diameters of 7 to 8 millimeters, and in lengths from 24 to 36 centimeters. The most commonly used lengths are from 28 to 34 centimeters



Fig. 281.—Compound segmented fracture of tibia treated by intramedullary fixation. Wound became infected intramedullary pin left in place. Proximal fracture united. Intramedullary pin removed bone graft of distal fracture was required before union was obtained.

Technic.—Following exposure of the fracture site (p 397) a two-inch longitudinal incision is made over the upper end of the tibia just medial to the tibial tubercle The bone is exposed subperiosteally Three or four holes are then drilled in the anterior cortex of the tibia With a chisel a slot of sufficient width to allow introduction of the intramedullary nail is created The nail is then directed at a flat angle, *directly* into the intramedullary canal down the length of the proximal fragment until it emerges at the fracture site The fracture is then reduced and the nail is driven into the distal fragment within

exposing the fracture site. So far as possible, the periosteal attachments on the anteromedial surface of the bone are preserved. With the aid of bone forceps, and traction the tibial fragments are rotated until accurately approximated, then held in position by Lane bone-holding forceps. Screws of appropriate length are inserted at a right angle to the longitudinal axis of the leg across both fragments (Fig 273) One should be certain that the screws transfix both fragments

After Treatment.—With the knee in slight flexion and the ankle in slight equinus a cast is applied from the groin to the toes. After ten days, the position of the fragments is confirmed by roentgenograms. At the end of three to four weeks, the cast is removed to permit examination of the extremity and removal of the stitches. Further roentgenograms are then made to determine whether the alignment has been altered. Thereafter immobilization is continued by means of a new snugly fitting cast. At eight weeks, if the degree of union warrants, the extremity is fitted with a brace which has a drop ring catch at the knee to permit flexion on sitting and active exercise and the patient is allowed to begin walking The brace generally includes a leather lacer corset from the ankle to the knee, to provide adequate immobilization and to prevent bowing at the fracture site from weight bearing After another month, free motion of the ankle is permitted in the brace The extremity should be supported for an additional four to six weeks.

If union of the fractured tibia is not completely solid at the end of eight weeks postoperatively, the extremity should be placed in a third cast with the knee as straight as possible. A rubber sole is incorporated on the bottom of the cast and weight-bearing is gradually resumed. As a rule after one month of weight-bearing in the cast, union is sufficiently advanced to justify the application of a brace If, after four to five months, union is not completely solid, the *institution of surgical measures for delayed union or nonunion may* be considered (Chapter X)

Short Oblique or Transverse Fractures

Fixation by a Plate and Screws—The fracture site is exposed as described above The periosteum is stripped from the ends of the fragments sufficiently on the lateral and medial aspects to permit the application of bone holding forceps. By traction and angulation, the fragments are apposed in proper alignment For transverse fractures, a four hole metal plate is placed on the lateral aspect of the tibia and fixed by screws (Fig 273) Before the screws are inserted the fragments are impacted for maximum contact and apposition. The insertion of a screw obliquely across a transverse fracture is neither necessary nor desirable

It is difficult to get a sufficient grasp on short oblique fragments to hold them in position while a plate and screws are applied To obviate this difficulty a single transfixion screw is inserted across the oblique fracture the fracture being held absolutely immobile until the screw has been inserted. If the hole must be drilled at a slightly oblique angle to the axis of the tibia, care must be exercised to avoid breaking the drill

If the oblique fragments are too short for a single transfixion screw the plate should be applied to the proximal fragment with one screw The distal

From this study, Knight made the following classification

1 External condyle

a Depression of the entire condyle, often associated with a fracture of the neck of the fibula Complete tears of the medial collateral ligament may be associated with this injury, not infrequently, there are tears of the cruciate ligaments or avulsions of their bony tibial attachment The tibial plateau is usually less comminuted than those in group (b)

b Lateral displacement of the rim of the tibial plateau with depression and comminution of the central portion of the condyle. This type may also be associated with ligamentous injury

2. Internal condyle

a Depression of the internal condyle, usually without medial displacement of the peripheral rim

3 Inverted T fractures of both condyles

a Comminuted crushing fractures of the entire tibial condyle.

b More severe injury of one condyle than of the other In this type, the depression and displacement of the most severely injured condyle is more important the transverse fracture may be ignored so long as the axial alignment of the bone is maintained.

Ordinarily, the damage to the articular surfaces is considerably more extensive than the preoperative roentgenograms would lead one to believe The bony attachment of one or both cruciate ligaments may be avulsed, lying as free fragments in the joint. Comminuted fragments of the articular surface often lie at angles to their normal plane and may be upside down. The semilunar cartilage is usually torn peripherally and a portion or all of the cartilage may lie between the comminuted fragments.

It is axiomatic that function following fractures involving the surfaces of joints, particularly weight bearing joints, is directly proportionate to the accuracy of restoration of the joint surfaces and re-establishment of length alignment and position. Open reduction of fractures of the condyle of the tibia is indicated when the displacement or depression is so severe as to give rise to varus or valgus deformities, instability, or gross incongruity of the articular surfaces. In all open reductions, regardless of the degree of comminution, the interior of the joint must be exposed and visualized in the roentgenogram.

The trauma which produces the injury is generally sufficient to induce an extreme reaction, accompanied by hemarthrosis of the knee Contusions and excoriations of the skin are common. Aspiration of the knee joint, skin traction and fixation, with wet dressings about the joint may be necessary for a period of ten days or longer before the reaction subsides to a degree which permits open operation.

Fracture of the Lateral Condyle of the Tibia

An understanding of the mechanism of fractures of the lateral tibial condyle is a necessary requisite to reconstruction. Barr has excellently described this as follows The cause of fracture of the external condyle is a valgus type of strain on the knee, the ligamentous structures and the muscles on the medial side tending to resist any separation of the medial, tibial and femoral condyles.

one inch of the ankle joint. Roentgenograms are made to ascertain the position of the pin. Prior to closure any rotational deformity or distraction at the fracture site is corrected.

After Treatment.—With the knee slightly flexed, the extremity is immobilized by a cast from the groin to the toes. The cast is bivalved to allow for swelling. Weight-bearing in a walking cast is not allowed until four to six weeks have elapsed. The intramedullary pin should not be removed from the tibia until definite maturity of the callus can be demonstrated and the fracture is solid. This will vary from four to six months.

Böhler permits active exercises, beginning at the second week, but no weight bearing for four weeks. He applies walking casts only following fractures of the lower half of the tibia.

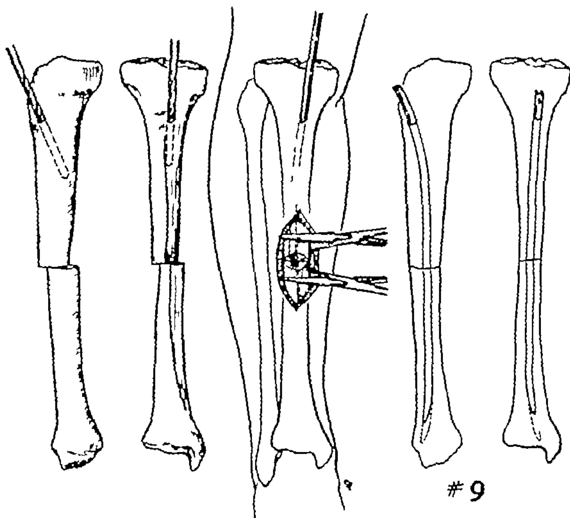


Fig. [illegible].—Technic of intramedullary fixation of tibia with Küntscher pin.

CONDYLES OF THE TIBIA

Knight, in 1945, reviewed the fractures of the tibial condyles which had been treated at Campbell Clinic. *The series consisted of 134 patients*, 81 of whom were treated by conservative measures and 53 by operations. The majority were injured either from a high fall or from ordinary torsional or lateral *strain on the knee joint*; a few had so-called bumper fractures from a blow by an automobile fender or bumper. In elderly individuals, the severity of the fracture was always far out of proportion to the amount of trauma sustained.

The following operative procedure is a combination of the technics described by Barr and by Knight.

Technic.—The incision is begun approximately one inch lateral to the superior pole of the patella, carried distally just lateral to the tibial tubercle thence downward and outward, to end about four inches below the joint line just anterior to the fibula. The lateral edge of the skin flap is reflected until the head of the fibula comes into view. The capsule is then incised. usually, the cartilage is torn traumatized or displaced to the degree that meniscectomy is in order. The articular surface of the tibial condyle may then be inspected with relative ease. On the contrary, a well preserved semilunar cartilage need not be indiscriminately removed merely for exposure. The cartilage on the lateral side covers a rather substantial portion of the external condyle and, therefore acts as a pad between the joint surfaces. Removal of the cartilage increases the gap between the edges of the condyle. If visualization of the articular surface of the condyle is difficult, the cartilage may be divided through its anterior and mesial synovial attachments. Therefore, it can be retracted and later replaced and carefully resutured. In our experience, subsequent derangement has not occurred.

To expose the longitudinal fracture of the lateral condyle, the origin of the extensor muscles is stripped from the anterolateral aspect of the outer condyle through an upside down L-shaped incision. The base of the incision extends laterally from the tibial tubercle for approximately one inch while the vertical limb passes downward two to three inches, just lateral to the crest of the tibia. The muscular origin is then reflected laterally until the fracture line is brought into view. Muscular attachments to the lateral fragment are left intact. Retraction of the lateral fragment affords excellent access to the central portion of the tibial condyle. The loose central fragments are replaced by means of a periosteal elevator or by grasping forceps. After the surface is elevated a defect remains which must be filled with autogenous bone unless this is done redisplacement and settling-down may take place. Until recently match stick tibial grafts were utilized being interlaced as a lattice work to form a supporting framework. The condyle of the corresponding femur or the bone bank, however is an excellent source of cancellous bone. The synovium and subsynovial tissues of the lateral or medial condyle, as the case may be are split longitudinally and elevated and a lateral cortical window is removed. The required amount of cancellous bone may then be obtained. The window is replaced in the defect in the femoral condyle and the wound is closed. With an inlay the cancellous bone is packed snugly in the defect in the tibial condyle. The lateral fragment is then replaced snugly to lock the articular fragments in a jigsaw puzzle fashion.

Either the Webb type stove bolt or Knowles pins may be utilized for fixation. A Knowles pin being threaded throughout the terminal one inch of its length, and thus serving as in a lag-screw has been found more satisfactory. Moreover the insertion of a Knowles pin may be better controlled than that of a wood screw or a stove bolt. The pin is also easily removed at a later date. The pins must be sufficiently long however to engage the opposite condyle securely. If the cortical bone is unduly fragile and osteoporotic a nut and washer may be inserted on the end of the Knowles pin. Fixation is inserted from the

The lateral femoral condyle drives downward into the weight bearing surface of the lateral tibial condyle depressing the central portion of the articular cortex well below its normal level, into the cancellous diaphyseal portion. In addition, the lateral margin of the articular cortex of the tibia bursts laterally and is associated with a fracture which runs longitudinally down into the shaft of the tibia. This lateral fragment usually is of fairly good size and, if seen from the lateral view is rather triangular in shape, the base of the triangle being proximal *As a rule, this lateral fragment does not displace downward* with the comminuted central portion instead, the intact fibula tends to serve as a buttress, holding the fragment at the joint level Less often, the lateral condyle may fracture the fibula at its neck in this event the lateral condyle may be displaced as one relatively large fragment, with only a slight central depression and comminution

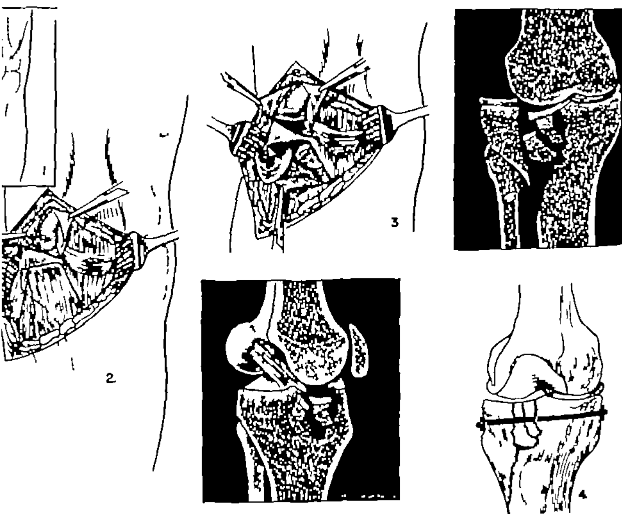


Fig. 290—Open reduction and internal fixation of fracture of external condyle of tibia (Barr) *1*, Skin incision. *2* Capsule of joint incised to permit inspection. L-shaped incision releases origin of extensor muscles. *3* Central portion of articular cortex, usually displaced below normal level of tibial plateau lateral margin of articular cortex bursts laterally *4*, After elevation of central portion and fixation with bolt. (From Barr J S. J A. M. A. 115 1683 1940)

Barr is of the opinion that conservative treatment may suffice if the displacement is less than one-fourth inch. If displacement is more than one-fourth inch we believe open reduction should be employed.

The end results are commensurate with the age of the patient and the accuracy of the reduction Although the comminution may prevent exact restoration of the joint surface function is satisfactory if the plateau is restored Roentgenograms seldom reveal perfect restoration of the contour of the tibial condyle In a large number of patients, particularly young individuals, a stable joint with a serviceable range of motion may be anticipated



Fig. 292.—*A*, Fracture of condyles of tibia. Displaced fragment includes all of medial condyle and a portion of lateral condyle. *B* Reduction maintained by Vitallium nail and Webb stove bolt.

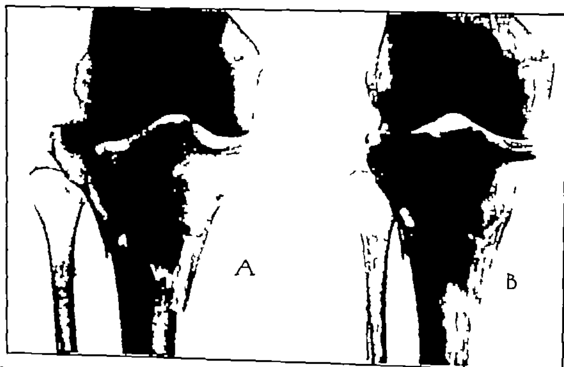


Fig. 293.—*A* Comminuted, inverted Y fracture of condyles of tibia. *B* After open reduction.

lateral aspect of the lateral fragment, directly transverse to the longitudinal axis of the leg and in a posterior and medial direction, emerging through the medial tibial cortex just posterior to its subcutaneous surface

If the fracture consists of only one large triangular segment, with slight or no comminution and little central depression, mere replacement of the fragment and fixation is adequate If there is little displacement of the peripheral rim, the central depression of the condyle being the predominating deformity, an anterior cortical window its upper edge about one-half inch below the articular surface, is removed. A small thin-bladed osteotome is then introduced through the window into the cancellous subchondral bone and the depressed portions of the articular surface are elevated to their normal level. Thereafter, the defect is filled with cancellous bone, as described above



Fig. 281.—*A* Typical fracture of external condyle of tibia. *B* After open reduction and fixation, tibial plateau has been restored.

After Treatment.—The knee is immobilized and a cast is applied from the groin to the toes maintaining the joint in slight flexion and in a varus position After two weeks, the cast is bivalved and the stitches are removed. Physical therapy and quadriceps set-up exercises are then begun. Gentle passive motion of the knee may usually be instituted at three weeks. Four to six weeks postoperatively if union progresses satisfactorily, the patient is allowed to walk with crutches, the leg being maintained in a drop-ring knee brace. Weight bearing is not permitted for from ten to twelve weeks following operation. A night splint should be worn to hold the knee in full extension until the quadriceps muscle regains sufficient power to extend the knee fully and there is no tendency toward flexion contracture.

of the humerus with displacement of the loose fragment between the humerus and ulna At operation, the capsule of the knee joint was found to be coiled up and pinched between the outer condyles of the femur and tibia. On displacing the capsule laterally the fragment appeared still attached to the external lateral ligament and a part of the biceps tendon The fragment was replaced and sutured with braided silk. Immobilization was continued for a period of ten weeks. An associated paralysis of the peroneal nerve cleared up during this period

PATELLA

A review of the literature reveals a wide diversity of opinion as to the proper treatment of a fractured patella, particularly with reference to patellectomy

In 1937, Brooke presented a revolutionary idea in suggesting that the patella was a phylogenetic inheritance and not a functional organ He stated that although the patella was a sesamoid bone there was no evidence that it developed in the quadriceps tendon in response to function that the extensor mechanism was more efficient and had more power if the patella was excised More recently however Haxton has made complete studies which refute all of these claims. He delved into the function of the patella from a standpoint of comparative anatomy, human embryology human anatomy experimental anatomy and the clinical results of patellectomy Haxton reported that any one who had removed a patella could certify that the patella actually gave attachment to the vast majority of the fibers of the quadriceps and patellar tendon that the bone actually transmitted tension produced by the quadriceps In experimental studies of patients with and without patellae, he demonstrated that the powers of extension of the knee increased as the joint extends in other words, more force could be produced with the knee at 150 degrees than at 60 90, or 120 degrees. This was true despite the law of von Schwann i e., that the tension of contraction diminishes as muscle fibers shorten. By comparison of normal subjects with patients who had had patellectomies, it was shown that patellectomy is followed by a loss of a greater part of this increase as the knee is extended. Since the extended position of the knee is the most important, one may conclude that patellectomy definitely impairs the efficiency of the quadriceps mechanism. This decrease, however may not be sufficient to interfere with ordinary activities.

There are other objections to the indiscriminate use of patellectomy for all fractures of the patella Although motion in the knee may be regained fairly rapidly the strength of the quadriceps mechanism returns slowly The obvious atrophy of the quadriceps muscle as compared with the normal side persists for months after patellectomy, despite diligent efforts to restore this muscle group to normal An additional disadvantage is the loss of the protective action of the patella to the knee joint. Wass and Davies call attention to a complication following patellectomy which has received relatively little attention, namely pathologic ossification This, they believe accounts for some of the pain and limited motion which follows excision of the patella. These observers state that the smaller ossifications are probably of no clinical significance In two of their cases however the new bone formation was sufficient to cause a loss of elasticity of the quadriceps tendon and thus a loss of flexion in the knee joint In these, return of function was prolonged

Fracture of the Medial Condyle of the Tibia

The principles of treatment of fractures of the internal condyle are similar to those followed in reduction of fractures of the lateral condyle.

Fractures of Both Condyles of the Tibia, or Inverted Y or T Fractures

Reduction of this fracture is extremely difficult. Even with a satisfactory reduction there may be considerable residual traumatic arthritis as a result of incongruity of the articular surfaces If one condyle is displaced more severely than the other the transverse fracture and the least displaced fragment are disregarded, and treatment is carried out as described for fractures of the lateral condyle of the tibia. If the axial alignment of the least displaced fragment is not satisfactory, open reduction and fixation must be carried out as described below A rather extensive exposure of the knee joint is necessary

Technic.—Two skin incisions are made as follows the lateral incision begins one inch lateral to the inferior pole of the patella and extends distally just lateral to the tibial tubercle thence downward and outward, ending approximately four inches below the joint line just anterior to the fibula. The lateral edge of the skin flap is reflected until the head of the fibula comes into view A second incision is next made on the anteromedial aspect of the knee, beginning at the level of the superior pole of the patella extending distally for three inches beyond the knee joint, and ending on the medial aspect of the leg The medial aspect of the skin flap is dissected back until the medial condyle of the tibia is readily accessible The capsule of the joint is then incised both medially and laterally to permit thorough inspection of the joint, and removal of the articular cartilages, if necessary By retraction of the fragments outward, the joint may be completely exposed. The damage to the internal structures of the knee is handled in much the same manner as that described for fractures of the lateral condyle of the tibia (p 401) Reduction is accomplished by traction on the leg while the condylar fragments are rotated into position. This procedure may be expedited by the insertion of two Knowles pins into the large fragments on each side the pins being used as levers to rotate the fragments into proper position. Thereafter a carpenter's clamp such as the Böhler clamp for the os calcis, may be utilized to maintain position of the fragments and the necessary counterpressure for insertion of the internal fixation. An adequate number of Knowles pins or stainless steel nails are inserted from cortex to cortex to provide fixation or if preferred, a stove bolt as suggested by Webb may be utilized. The fixation material must be of sufficient length to traverse both fragments completely Roentgenograms should be made prior to closure of the wound to insure proper apposition of the fractured surfaces and proper placement of the internal fixation

After Treatment.—The after treatment is similar to that for fractures of the external condyle of the tibia (p 404), although the initial immobilization in the cast must be maintained for at least six to eight weeks.

FIBULA

Avulsion Fractures of the Proximal End of the Fibula

Watson-Jones reports one case of rupture of the lateral ligament and an avulsion fracture of the fibula wherein the loose fragment was displaced between the joint surfaces, an injury analogous to fracture of the internal epicondyle

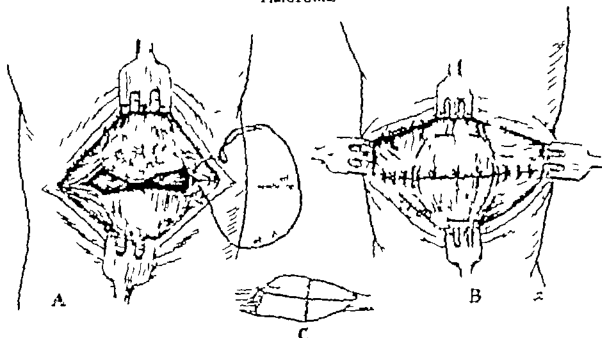


Fig 334.—Open reduction of fracture of patella. Fixation of fragments by circumferential wire loop. Lateral tears in capsule and synovial membrane repaired with catgut.

Technic (Martin).—A 0.5 mm rustless steel wire is threaded upon a large Gallie needle and inserted transversely from the lateral to the medial side through the quadriceps tendon just above the proximal border of the patella, then passed along the medial border of both fragments midway between the anterior and posterior surfaces. The needle and wire are next passed transversely through the patellar tendon from the medial to the lateral side, in close proximity to the lower border of the patella, thence upward along the lateral aspect of the patella to its proximal and lateral border The wire *must* be placed close to the patella, particularly above and below, if inserted through the tendons at a distance from the fragments, perfect fixation is lost as the wires may cut the tendons when under tension, permitting separation of the fragments. The fragments are approximated and held in position by a small towel clip as both ends of the wire are drawn tight and twisted together Approximation and reduction of the fragments, particularly the relation of the articular surfaces, should be confirmed by roentgenograms of the knee in both the anteroposterior and lateral planes. In some cases, the approximation is so complete that the fracture is recognized with difficulty The redundant wire is then severed and the twisted ends depressed into the quadriceps tendon

After Treatment.—A posterior gutter splint extending from the groin to the ankle provides sufficient immobilization After ten days the stitches are removed, and if the condition of the wound will permit, active and passive exercises are begun with the aid of an overhead pulley Physical therapy is advisable if the patient is beyond forty years of age. On the fourteenth day walking is allowed with crutches as muscle power returns, the crutches are discarded Ninety degrees of motion usually is present by the end of eight weeks.

Removal of the wire is necessary in a few cases. This is a negligible disadvantage as the loop may usually be located through a small stab wound under local anesthesia the wire is cut at the loop and withdrawn with little difficulty

In view of the above observations, we subscribe to a middle of the road course in the treatment of fractures of the patella. In simple transverse fractures without comminution, the tendon and fractured patella are apposed by a circumferential wire loop as originally described by Denegre Martin. If the lower pole of the patella is comminuted, the fragments are removed, though the large fragment is preserved (Thomson). In the presence of excessive comminution of the patella all fragments are excised (Brooke).

If the skin is in normal condition, the operation should be carried out as early as possible. Delay is not only unnecessary but materially impedes recovery and to some extent affects the end results adversely. If contusion or laceration of the skin is excessive special preoperative measures must be carried out. The extremity is placed in a posterior splint with the knee extended, and warm wet dressings of some bland solution, as boric acid or penicillin packs, are applied for a week or ten days, or until the danger of postoperative infection is minimized.

Approach and Technic Common to Most Procedures

A transverse curved incision approximately three inches in length, the apex of the curve over the distal fragment, will give an adequate exposure for reduction of the fracture and repair of the ruptured capsule and synovium. If there is severe contusion of the skin, this area must be avoided by placing the incision either proximal or distal to the routine curve, or a lateral or medial longitudinal approach may be necessary.

The line of fracture is exposed and the extent of the tears in the capsule and synovium on each side is determined. All completely detached particles of bone are removed from the fracture site. The interior of the joint is cleared of sanguineous fluid or blood clots and meticulously inspected for particles of bone. Routine roentgenograms made during the course of the operation will reveal those undiscoverable by inspection.

The ruptured capsule and synovium are released from tension by fixation of the quadriceps and patellar tendons, and are then repaired from the lateral edges toward the midline of the joint with interrupted or mattress stitches of No. 1 chromic catgut.

Transverse Fracture of the Patella

The fragments of a transverse fracture may be fixed by either of the following technics:

(1) *circumferential wire loop* (Denegre Martin)

(2) wire loop through both fragments (Magnuson)

Excellent results are obtained by any procedure wherein the articular surface of the patella is accurately apposed and internal fixation is adequate. For uncomplicated transverse fractures, we prefer the circumferential wire loop.

Circumferential Wire Loop

A suture which circumscribes the patella is a particularly effective means of fixation. The technic is relatively atraumatic and may be rapidly carried out. Fixation of the fragments is sufficiently secure to permit early mobilization of the knee.

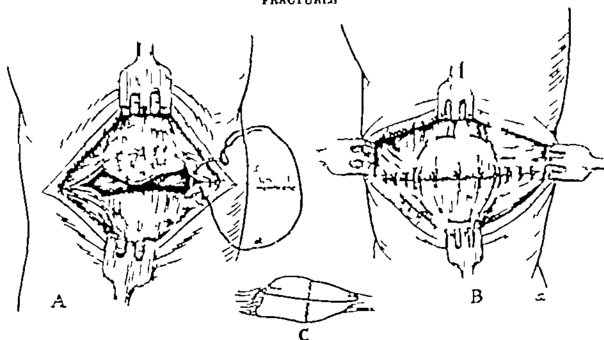


Fig. 294 —Open reduction of fracture of patella. Fixation of fragments by circumferential wire loop. Lateral tears in capsule and synovial membrane repaired with catgut.

Technic (Martin) —A 0.5 mm rustless steel wire is threaded upon a large Gallie needle and inserted transversely from the lateral to the medial side through the quadriceps tendon just above the proximal border of the patella, then passed along the medial border of both fragments midway between the anterior and posterior surfaces. The needle and wire are next passed transversely through the patellar tendon from the medial to the lateral side, in close proximity to the lower border of the patella thence upward along the lateral aspect of the patella to its proximal and lateral border The wire *must* be placed close to the patella, particularly, above and below, if inserted through the tendons at a distance from the fragments, perfect fixation is lost, as the wires may cut the tendons when under tension permitting separation of the fragments. The fragments are approximated and held in position by a small towel clip as both ends of the wire are drawn tight and twisted together Approximation and reduction of the fragments, particularly the relation of the articular surfaces, should be confirmed by roentgenograms of the knee in both the anteroposterior and lateral planes. In some cases, the approximation is so complete that the fracture is recognized with difficulty The redundant wire is then severed and the twisted ends depressed into the quadriceps tendon.

After Treatment.—A posterior gutter splint extending from the groin to the ankle provides sufficient immobilization. After ten days the stitches are removed, and if the condition of the wound will permit, active and passive exercises are begun with the aid of an overhead pulley Physical therapy is advisable if the patient is beyond forty years of age On the fourteenth day walking is allowed with crutches as muscle power returns, the crutches are discarded Ninety degrees of motion usually is present by the end of eight weeks.

Removal of the wire is necessary in a few cases. This is a negligible disadvantage as the loop may usually be located through a small stab wound under local anesthesia the wire is cut at the loop and withdrawn with little difficulty

Wire Loop Through Both Fragments

Technic (Magnuson) —With a No 19 drill two holes are made in the proximal fragment, beginning at the medial and lateral borders of the quadriceps tendon, and carried obliquely downward to open on the fractured surface of the patella posterior to a point midway between the anterior and posterior surfaces of the patella. Two corresponding holes are drilled in the distal fragment, their apertures being opposite those in the proximal fragment. A stainless steel 0.5 mm wire is then threaded down through the medial holes and up through the lateral holes. *After* proper approximation of the patellar fragments, the ends of the wire are drawn taut, twisted together and embedded in soft tissue

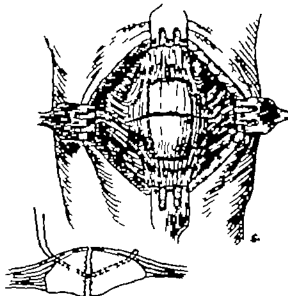


Fig. 295.—Magnuson method of open reduction of fracture of patella.

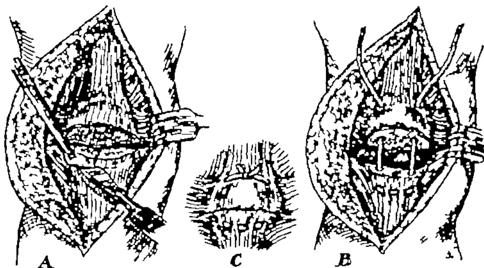


Fig. 296.—Open operation for fracture of patella according to Thomson. Smaller distal fragment of patella is removed. Continuity of patellar tendon restored by strip of fascia lata. (Redrawn from Thomson, J E M. J Bone & Joint Surg. 17: 431, 1935.)

Comminuted Fractures of the Distal Half of the Patella

Technic (Thomson) —The comminuted portion of the patella and torn shreds of tendon are removed. Two holes are drilled vertically in the large fragment, opening on the fractured surface just anterior to the articular

cartilage A strip of fascia lata is excised from the thigh and sutured through the patellar tendon Each end of the strip is passed upward through its respective drill hole in the large fragment and drawn taut above, and the ends are sutured together (Stainless steel wire may be substituted for the fascia lata)

Complete Excision of Patellar Fragments

In the presence of gross comminution, patellectomy, or complete excision of the patella is indicated

Technic.—The fracture is exposed by a transverse incision as described above (p 408) The comminuted fragments of the patella are removed from the quadriceps and patellar tendons by sharp dissection The shredded edges of the tendon are trimmed the joint is thoroughly inspected for loose fragments, and finally the quadriceps and patellar tendons are approximated by a mattress suture of 0.5 mm stainless steel wire The tendon and capsule should be overlapped and plicated to take up the slack from loss of the patella

After Treatment.—(See p 409)

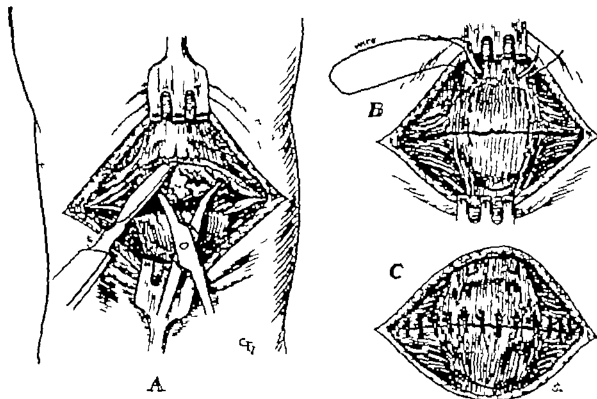


Fig. 29 —Patellectomy for comminuted fracture of patella. A Fragments exposed and excised through transverse incision. B Quadriceps and patellar tendons joined by mattress suture of wire. C Repair completed.

OSTEOCHONDRAL FRACTURES OF THE KNEE

During World War II, attention was called to a lesion which had previously been reported but had received little notice In a survey by the Army Air Force, approximately 180 cases of loose bodies in the knee joint were studied In 21 of these, the loose bodies were produced by osteochondral fractures of either the femur or of the patella Loose bodies from the femoral condyle were usually produced by a direct sharp blow on the margin of the joint. In 15 cases, the fragments originated from the patella, a piece of the articular surface having been sheared off together with a small segment of cancellous bone

According to Milgram, the mechanism of the injury to the patella is as follows The patella momentarily subluxates over the outer condyle with sufficient force to score the articular surfaces of the patella and femur The medial border of the patella is then caught against the prominent edge of the femoral condyle. As the quadriceps muscle snaps the patella back into line, the edge of the femoral condyle rips an osteochondral layer off the inferior and medial edge

Treatment of osteochondral fractures consists of exposure of the joint, and the location and removal of the loose body Raw cancellous surfaces on the patella or the femur are smoothed down, and any detached or frayed edges of the cartilage are excised.

Since the area involved is usually relatively small, slight, if any disability will ensue.

LOWER THIRD OF THE FEMUR

In fractures of the lower third of the femur a fairly perfect anatomic reduction is necessary for a successful functional result. This is particularly true if the condyles and the articular surfaces are involved. In contrast to the tibial condyles, compression or depression fractures of the femoral condyles are rare unless a pathologic process with osteoporosis is present Open reduction is required most often for T fractures, condylar fractures, and epiphyseal separations.

T Fractures of the Condyles of the Femur

Technic.—A lateral incision is made parallel to the shaft of the femur beginning at the knee joint and extending proximally four inches. The distal portion of the iliotibial band and of the vastus lateralis muscle are incised longitudinally By dissection close to the bone the anterior surface of the femur at the fracture site is exposed, the anterior portion of the vastus lateralis muscle being retracted forward The suprapatellar pouch is avoided so far as possible Frequently the shaft of the femur is wedged between the two condyles in this event, traction on the leg with the knee flexed will displace the shaft. The shaft fragment is temporarily ignored A six hole stainless steel plate, previously bent to conform to the lateral contour of the lower third of the femur (Fig 298A) is applied to the lateral surface of the femoral condyle. A Knowles pin of proper length is inserted in the distal hole and drilled into the lateral condyle Through another incision on the medial side a second Knowles pin is drilled into the medial femoral condyle. Both pins are then used as levers to maneuver the two condyles into proper approximation, reduction being verified by direct visualization. The lateral Knowles pin is next drilled across the fracture site and through the medial condyle Over its protruding end on the medial side, a nut and washer are applied to further compress and approximate the fragments. This procedure converts the T fracture into a supracondylar fracture The shaft is now approximated to the condyles and the plate is properly applied to the shaft and fixed by three screws. If possible, a second screw or Knowles pin is introduced at an oblique angle into the condylar fragment.

After Treatment.—The knee is held in 135 degrees flexion and a plaster cast is applied from the toes of the affected side to the crest of the ilium. After four weeks, the cast is bivalved the stitches are removed and the general align

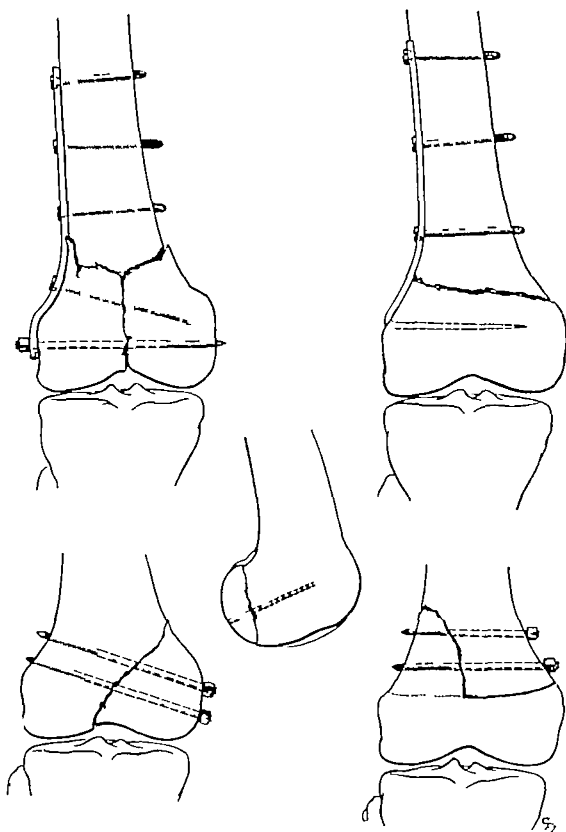


Fig. 298.—Methods of fixation of fractures of lower end of femur *A* T fracture fixed by bolt, plate, and screws. *B* Supracondylar fracture held in position by a Blount blade plate and screws. *C*, Internal condyle immobilized by two Knowles pins. *D* Partial separation of lower femoral epiphysis immobilized by Knowles pins through metaphyseal portion of bone. *E* Fracture of posterior condyle fixed with one wire nail.

ment of the extremity is observed. Roentgenograms are made to verify maintenance of the position of the fragments. A spica cast is then reapplied, to be worn for an additional six weeks. At the end of ten weeks postoperatively, union is usually sufficiently solid to permit active and passive motion and physical therapy. Convalescence is likely to proceed slowly. In young patients, walking with crutches may be permitted as soon as the knee can be extended sufficiently for the application of a long leg brace with a drop ring catch at the knee. Because of its subcutaneous location at the condyle the metallic fixation must eventually be removed.

The end results depend much upon the age of the patient. Rarely is normal function secured although motion ranging from full extension (180 degrees) to 130-90 degrees flexion is obtained in the majority of cases. Unfortunately movements cannot, as a rule, be instituted early. After long fixation, moreover permanent contractures of the anterior structures or adhesions between the quadriceps tendon and femur may necessitate further operative procedures (Chapter XVI).

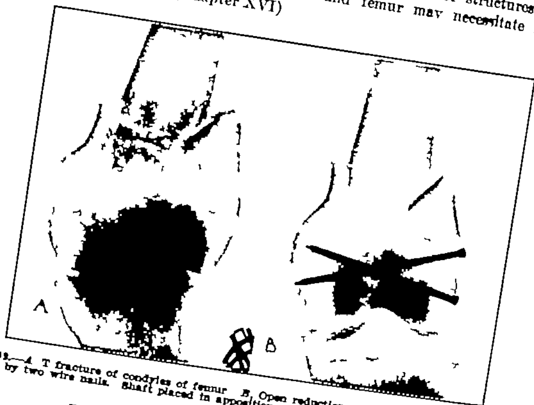


Fig. [illegible].—A, T fracture of condyles of femur. B, Open reduction, condyles maintained in position by two wire nails. Shaft placed in apposition with condyles and maintained by cast.

Fractures of the Medial Condyle of the Femur

When only one condyle is fractured, the operation is relatively simple as the shaft of the bone is not involved and internal fixation is sufficiently effective to permit fairly early movement.

Technic.—A longitudinal incision is begun at the knee joint well anterior to the relaxed internal hamstring tendons and extended proximally four inches. The vastus medialis muscle is incised longitudinally and the loose fragment, which may consist of the entire condyle or only the posterior one-half is exposed. Two rustless steel nails or Knowles pins are drilled into the fragments so placed that they may serve as levers for proper reduction. When

anatomic apposition is apparent on direct examination, the pins are drilled across the fracture line at a slight angle to each other for four fifths of their length Roentgenograms are then made in two planes to verify the correct approximation If the alignment and position are correct, fixation is completed The stud on the end of the Knowles pin should be snugly approximated to the medial cortex, while the distal end of the pin should protrude through the opposite cortex by one-eighth to one fourth inch The lag screw effect of the Knowles pin produces snug fixation

After Treatment.—A plaster cast is applied from the toes to the crest of the ilium After four weeks, the cast is bivalved and active and passive motion and physical therapy are begun At six weeks postoperatively, walking with crutches is permissible the knee being protected by a long leg brace. At the end of eight weeks, partial weight bearing in the brace is allowed, and one month later full weight bearing is resumed the brace being discarded if union is sufficiently firm.

Isolated fractures of the femoral condyle are not often attended by a material degree of residual disability

When reduction has been accurate, a wide range of motion is regained by this method

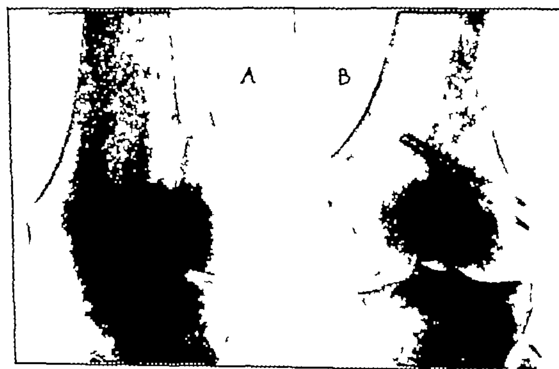


Fig 369—A Fracture of lateral condyle of femur B Reduction maintained by two wire nails.

Fracture of the Lateral Condyle of the Femur

For exposure of the lateral condyle of the femur see p 175 The technic is similar to that followed in reduction of fractures of the medial condyle.

Fracture of the Posterior Condyle of the Femur

The relatively innocuous appearance of this fracture in the roentgenogram belies its importance As seen in the lateral view the loose fragment consists of approximately the posterior one half inch of a condyle, usually the medial

one The loose fragment is devoid of blood supply, and practically its entire surface is covered with articular cartilage. The amount of displacement is minimal (Fig 397)

If the loose fragment is not properly apposed to the main fragment of the condyle, incongruity of the articular surface and aseptic necrosis of the loose fragment follows, with considerable pain and disability Since the loose fragment is an important part of the articular surface when the knee is flexed to 90 degrees, *its removal is not desirable. Treatment consists of* exposure and fixation of the fracture in proper position

Technic.—Exposure may be obtained by either the Henderson medial incision (p 144) or by an approach from the posteromedial aspect of the joint in much the same manner as for a cyst or semimembranous bursa. The former is preferable After exposure of the joint a portion of the origin of the medial head of the gastrocnemius must be incised and the muscle retracted toward the midline for ready access to the posterior aspect of the loose fragment. The loose fragment is properly apposed to the medial condyle and held in position while a stainless steel nail is driven in a posterior anterior direction. After the position has been checked by roentgenograms, the nail is countersunk below the level of the articular surface

After Treatment.—Immobilization is continued only long enough for the wound to heal thereafter active and passive exercises are instituted. Unprotected weight bearing may usually be allowed eight weeks postoperatively

Separation of the Lower Femoral Epiphysis

Operation is seldom necessary for replacement of a displaced lower femoral epiphysis unless the displacement is perfectly reduced, however, there will be pronounced irregularity or cessation of growth on either or both sides of the epiphysis, with subsequent deformity or shortening The entire epiphysis may be separated, or only a portion may be displaced in connection with an oblique fracture of the lower third of the shaft of the femur The epiphysis usually is displaced anteriorly

Technic.—The epiphysis is exposed through the lateral incision described above for T fractures of the condyles. The fracture is reduced as nearly as possible by manual traction and leverage, if the use of instruments is necessary *to reduction, trauma to the epiphyseal cartilage* should be avoided. Interposed soft tissue is removed and the epiphysis gently maneuvered into proper position. Internal fixation is, as a rule inadvisable, since this in itself damages the epiphysis and promotes early fusion of the joint and cessation of growth

After Treatment.—A plaster cast is applied from the toes to the crest of the ilium on the affected side, holding the knee and hip in 135 degrees flexion. As union is generally firm by the end of four to six weeks, active and passive motion and physical therapy may then be instituted. Weight bearing is permitted after eight weeks.

Even though perfect reduction is secured by manual force, there may be some loss of length in the affected extremity when full growth is attained. The amount of shortening will depend upon the age and growth of the patient at the time of injury and whether or not reduction is accomplished immedi

ately For example, if the patient is twelve years of age and the displacement is corrected promptly, the ultimate loss of length may be one half to one inch If growth is arrested at six to eight years of age, the ultimate difference in length of the limbs may be as great as three inches

Fracture of the Shaft of the Femur With Partial Separation of the Epiphysis

When an oblique fracture of the lower third of the femur extends downward into the epiphysis, the latter is displaced anteriorly remaining attached to a triangular fragment of the metaphysis. The dimensions of the metaphyseal fragments are as a rule ample for efficient internal fixation



Fig. 391.—*A*, Separation of lower femoral epiphysis. The distal fragment includes a portion of the shaft on the lateral aspect. *B* Anatomic reduction maintained by two wire nails.

Technic.—The fracture is exposed through a longitudinal lateral incision (p 178) the bony fragment connected with the epiphysis usually being on this side. Reduction is effected by traction and manual force, and the fragments are held in place while two Knowles pins are drilled across the line of fracture proximal to the epiphyseal line.

After Treatment.—(p 416)

Even though perfect reduction is accomplished, development of the epiphysis may be altered as following complete separation of the epiphysis.

SHAFT OF THE FEMUR

The majority of fractures of the shaft of the femur may be treated conservatively Anatomic apposition of the ends of the fragments is not required with even slight contact, nonunion is relatively uncommon a fair margin of er

ror so far as alignment and shortening are concerned, is compatible with good function. The principal disadvantages of conservative treatment are the secondary effects incident to prolonged immobilization, namely, limitation and restriction of motion in the knee joint, or at least a prolonged convalescence before motion in the knee joint is regained and the function of the soft parts approaches normal Following a fracture of the femur the average period of convalescence is approximately one year Perhaps this problem in the treatment of fractures of the femur may be solved by the use of intramedullary pins. This method seems to hold great promise for the future.

Open methods may be necessary because of an inability to appose or maintain the fragments properly The indications for open methods increase with fractures near either extremity of the shaft Oblique fractures of the shaft may be the occasion for electing open reduction and transfixion screws in preference to more prolonged and less certain technics.

The poor results from the indiscriminate use of plates and screws manifest themselves particularly following application of this procedure to fractures of the shaft of the femur The inexperienced are prone to make the following mechanical errors (a) apply plates which are too weak or too short for adequate fixation (b) insert screws through only one cortex (c) utilize drills which are too large or drill the holes improperly so the screws are not snugly seated in the bone (d) apply the fixation so as to permit slight distraction of the fragments.

A common error is the assumption that internal fixation is so stable that one may dispense with external fixation. This leads to bending or breaking of the plate or screws, and a loss of fixation Frequently this process takes place so gradually that rather marked deformity or malunion of the fracture takes place before the gravity of the situation is realized. The addition of a low-grade infection incident to poor technic creates a major reconstruction problem Thereafter removal of the plates and screws may be extremely difficult and the bone develops an avascular sclerotic quality for several inches on each side of the fracture site. Also a flare up of infection following subsequent operation is common. Altogether the picture is rather dismal In summation, we would say that a more conservative attitude should be adopted toward the treatment of fractures of the shaft of the femur than of fractures of any other long bone Open reduction and internal fixation should never be undertaken unless the surgical environment and technic are ideal.

The methods of fixation for the shaft of the femur are essentially those employed for the other bones, namely (a) for long oblique or torsional fractures, transfixion by screws (b) for short oblique or transverse fractures, a plate and screws (c) for fractures of four or more weeks' duration, particularly if associated with comminution onlay bone graft (d) the use of the intramedullary pin as described below

The detailed technic of open reduction and internal fixation by the various methods will not be included in this discussion The approaches to the shaft of the femur are described elsewhere for the middle third of the shaft, the anterior incision (p 173) provides the best exposure for the upper third and lower third lateral approaches are utilized (pp 179 and 175) Details as to the application of plates and screws are described on p 374



Fig 303.—Torsional, or long oblique fractures of lower third of femur may be adequately immobilized by transfixion screws.

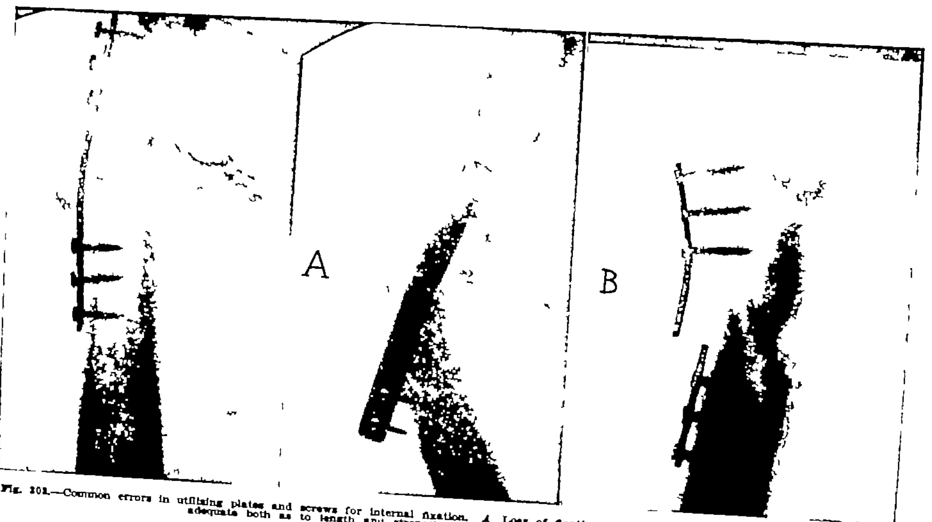


Fig. 301.—Common errors in utilizing plates and screws for internal fixation. *A*, Loss of fixation from improperly inserted screws. *B*, Plate inadequate both as to length and strength. Screws inserted through only one cortex.

After Treatment.—Immobilization is instituted by a cast extending from the nipple line to the toes on the affected side and to the knee on the opposite side, the hip and knee being maintained in 150 degrees flexion The position relaxes the pull of the gastrocnemius muscle below and the iliopsoas muscle above Roentgenograms are made at one four, eight, and twelve weeks postoperatively to demonstrate the position of the fragments and the progress of union In adults consolidation is usually not sufficiently advanced to permit active motion and walking until twelve weeks have elapsed As a rule when walking is permitted, the fracture site is protected for an additional three months by an appropriate brace which extends from the nipple line to the ankle As soon as plaster immobilization is discontinued physical therapy is instituted, with special attention to the knee Usually function of the hip and ankle is rapidly restored

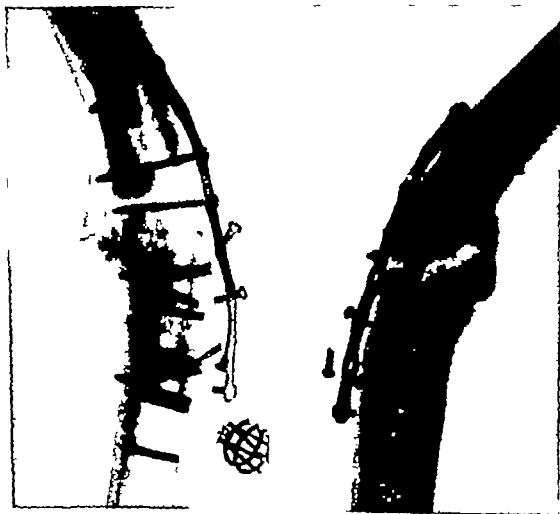


Fig. 304 —External fixation may not be dispensed with until union is solid, else the plate and screw must inevitably bend, break, or pull out of bone. In this case, nonunion, multiple pieces of metal, and a low grade of infection create a serious reconstruction problem.

Skeletal traction in a balanced splint (Fig 25) also provides a very satisfactory form of after treatment.

Intramedullary Fixation of Fractures of the Femur—A transverse fracture of the middle third of the femur is most favorable for intramedullary fixation In this fracture, all of the obvious advantages of the intramedullary

method accrue The femur is relatively straight and the fixation may be introduced in the supratrochanteric region in a direct line with the intramedullary canal. The intramedullary canal is ample to accommodate a large, strong pin. In fractures of the middle third, the pin passes for a sufficient distance above and below the fracture site to provide firm, stable fixation. External fixation is unnecessary and supervised exercises may be begun as soon as the pain and soreness subside This situation does not exist, however if the fragments are severely comminuted or if the fracture is not in the middle third. Under the latter conditions, intramedullary pinning must be supplemented by a balanced

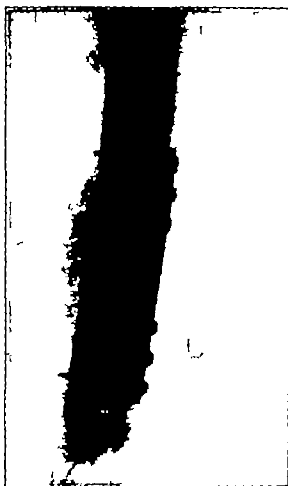


Fig. 30L—Plate of proper dimensions extends well below and above fracture site. Screws traverse both cortices. Internal fixation by plates and screws must invariably be supplemented by some form of external fixation.

splint and by skeletal traction Unless the pin can extend beyond the fracture site at least four inches on the short side, it should not be used fractures in the proximal or distal third which meet these requirements must be supplemented by some form of external fixation. Thereby some of the advantages of the method are obviated.

If the Küntscher femoral pin is utilized it should be available in lengths from a minimum of 28 cm. to a maximum of 52 cm the intervening lengths varying 2 cm. lengths from 38 to 46 cm are most widely used. In diameter the pins should be 9 10 or 11 mm., the small diameters being in the shorter lengths and the larger diameters in the longer lengths The proper size and length of the

nail should be determined before operation (p 367) If the Hansen-Street diamond-shaped rod is utilized only one diameter is available

In elderly individuals if the femur frequently shows considerable lateral and anterior bowing intramedullary pinning is not applicable

Technic.—The patient is placed on the table in a supine position with a large sandbag beneath the buttock on the affected side Traction is maintained by an assistant while the extremity is draped The entire field should be draped so as to permit easy maneuvering of the entire extremity while preserving a sterile field from the trochanter distally to below the knee throughout the operation, a Kirschner wire through the femoral condyles facilitates the procedure. The

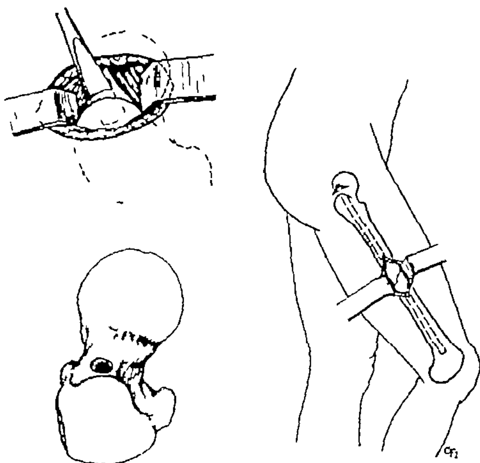


Fig. 304.—Intramedullary fixation of femur with Hansen-Street pins. Diamond-shaped pin inserted in hole in supratrochanteric region. Fracture site exposed and pins driven into distal fragment under direct vision.

fractures of the middle third of the femur are best exposed through an anterior incision (p 173) which is limited to a length just sufficient to expose the ends of the fragments With the hip flexed 45 degrees and the thigh adducted as far as possible, a small incision is made over the trochanter the fascia is incised, and the fibers of the tendinous insertion of the gluteus muscle are divided longitudinally The supratrochanteric portion of the femur is exposed at the junction of the neck and the medial border of the trochanter A hole is created in this area by means of a drill and a gouge The Hansen-Street pin is then introduced in the line of the femur through this hole into the intramedullary portion of the proximal fragment, and driven with a mallet as far as the fracture site With the fragments in their proper rotary relation and in proper align

ment, the pin is then driven farther into the *proximal fragment*. Roentgenograms are then made to determine whether the length of the pin is proper before it is driven into the distal diaphysis.

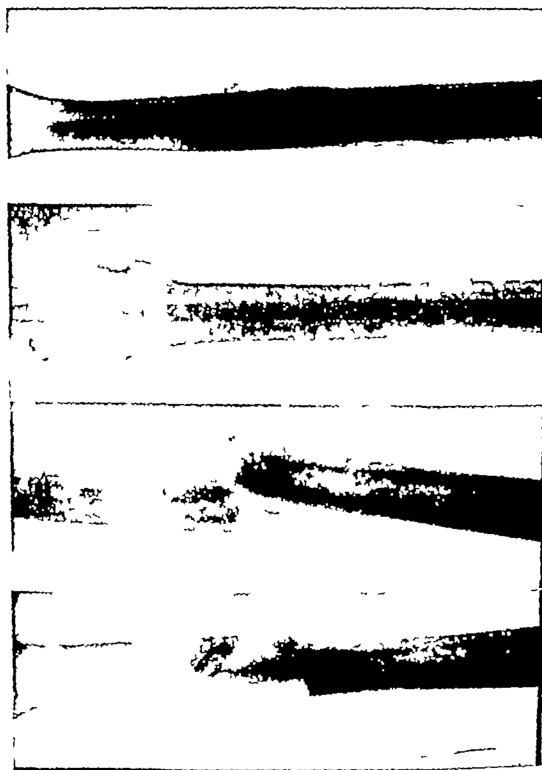


Fig [illegible] —A, Nonunion of fracture of femur in a paraplegic patient. B, Five months after insertion of intramedullary pin. (Courtesy of Dr D. Street.)

Prior to closure of the wound, any distraction is corrected by a force applied to the flexed knee.

Retrograde Insertion of Küntscher Pins *for Fractures of the Femur* — The preliminaries are carried out as described above After exposure of the frac-

ture site the distal end of the proximal fragment is lifted out of the wound. The size of the pin is determined by the diameter of the bone *at the fracture site*. The pin should fit snugly (not too tightly, nor too loosely). A guide pin is then introduced into the intramedullary canal of the proximal fragment and passed through the supertrochanteric region of the femur and out through the skin. A skin incision sufficiently long to allow the insertion of a Küntscher intramedullary pin is next made adjacent to the exit of the pin. The Küntscher pin is superimposed upon the guide pin until it comes into contact with the supertrochanteric region; thereafter, it is driven through the trochanteric region down through the intramedullary canal of the proximal fragment, and out at the fracture site. The guide wire is then removed, the fracture reduced, and the intramedullary pin driven into the distal intramedullary canal.

After Treatment.—The extremity is immobilized in a suspended splint for at least two weeks. If the fracture is comminuted or fixation is not stable, this is supplemented by skeletal traction. Exercises are begun at the end of two weeks. The patient is not allowed out of bed, however, until the elapse of six weeks. If callus is adequate, weight-bearing with crutches is allowed at the end of ten to twelve weeks. Intramedullary pins should not be removed until functional changes are evident in the callus and union is definitely established, which is usually from six months to one year.

FRACTURES OF THE HIP

Fractures of the hip are divided into two general types: those of the trochanteric region, and those involving the intracapsular portion of the neck of the femur. (Fracture-dislocations of the hip and fractures of the acetabulum are discussed in Chapter VII.) Approximately 80 per cent of both types of fractures takes place in individuals over 60 years of age and both are more common in women than in men (80 to 85 per cent). This is probably due to several factors. Women have a slightly wider pelvis with a tendency to coxa vara; they are usually less active and more prone to senile osteoporosis, and the life expectancy of a woman aged 60 is five years longer than that of the average man.

The prognosis of the two fractures is entirely different. Fractures of the trochanteric region practically always unite if reduction and fixation are properly carried out, and late complications are exceedingly uncommon. A wide area of bone is involved, the major portion of which is cancellous, and both fragments have an adequate blood supply. The question in regard to fractures of the trochanteric region is primarily one of survival. With rare exceptions, if the patient survives the long period of convalescence, the end result will be satisfactory. Fractures of the neck of the femur involve a constricted area wherein there is comparatively little cancellous bone; the periosteum is thin and there is no cambium layer. The blood supply to the distal fragment is usually adequate, though the blood supply to the proximal fragment may be impaired or may be entirely lacking. Because of the impaired blood supply, aseptic necrosis of the head of the femur and late degenerative changes often follow; basilar fractures of the neck are seldom associated with this complication, but nonunion is not uncommon.

Our experience with internal fixation has been so gratifying that this procedure is routinely employed for practically all fractures of the hip in adults.

Unless the patient is moribund the indication for internal fixation is inversely proportionate to the general condition of the patient in fact, internal fixation may offer the only hope of survival. Other than an occasional fracture without displacement, internal fixation should be performed under general anesthesia. The newer methods, such as pentothal work out quite well with a minimum of complications

TROCHANTERIC FRACTURES

(Subtrochanteric, Peritrochanteric, Intertrochanteric)

The term, trochanteric fracture, is used herein to include any fracture from the extracapsular portion of the neck to a point two inches below the lesser trochanter In general the type of treatment and internal fixation is practically the same for this entire group though there are little refinements of technic applicable to each region which facilitate reduction and fixation

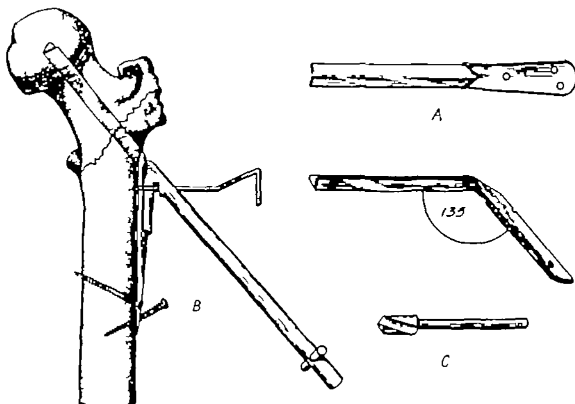


Fig. 398.—Fixation of intertrochanteric fracture by Neufeld nail. A Design of nail. B Relation of pin to fracture Inserter in place. C Burr provides hole in cortex for easy insertion of pin. (Courtesy of Dr A J Neufeld.)

The results of closed methods of treatment are satisfactory so far as the fracture itself is concerned. The mortality rate, however is relatively high Further following prolonged immobilization, function of the extremity particularly motion in the knee, is regained slowly in fact, permanent limitation of motion is not uncommon.

J S Speed and Boyd have recently studied a comprehensive group of trochanteric fractures treated at the Campbell Clinic by internal fixation with special reference to the mortality and morbidity rates. The mortality rate for trochanteric fractures was 18 7 per cent, approximately 4 per cent higher than *for central fractures of the neck of the femur* They attribute this to the fol

lowing the average patient is slightly older (4.5 years), trauma required to produce the fracture, is more severe and, finally, the *operative treatment* is considerably more extensive than for fractures of the neck of the femur

Internal fixation of trochanteric fractures has undoubtedly reduced the mortality rate and, certainly the morbidity rate Cleveland has estimated that senile psychosis will develop five times as often if the patient is treated by the use of a cast Medical complications following internal fixation are materially fewer and less serious than those incident to continuous rest in bed in a body cast Unquestionably the disadvantages of internal fixation of trochanteric fractures are far outweighed by its advantages.

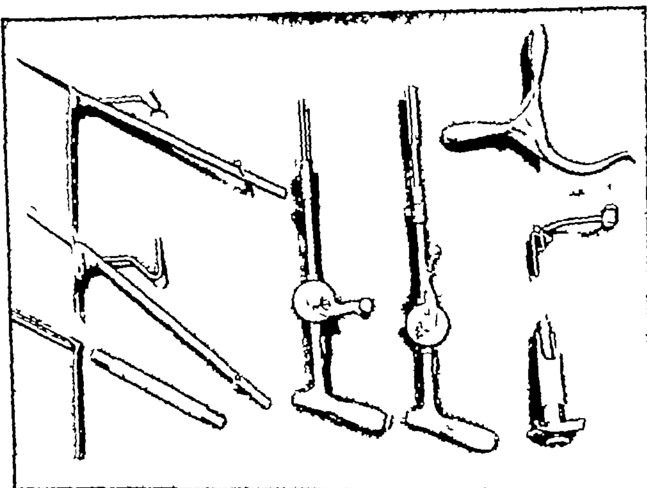


Fig 169 —Special instruments for fixation of trochanteric fractures: Moore blade plate and inserter Neufeld nail and inserter Jewett nail and impactor drill and guide pin, drill and cannulated reamer Blount anvil retractor guide and extractor for Jewett nail.

Various types of nails and pins have been devised to fix trochanteric fractures. One of the early types was devised by Lawson Thornton in 1937 This consisted of a plate one end of which fitted over the head of a Smith Petersen nail and was fixed thereto by means of a screw Jewett varied this method by welding the blade to a Smith Petersen nail. Moore suggested a blade-type plate Neufeld devised a V-shaped nail, bent at 135 degrees to conform to the angle of the neck and shaft. In the majority of cases, we have employed either a Neufeld or a Jewett nail The latter is considerably stronger and will undergo more stress and strain, and thus is preferred for fractures in the region of the

lesser trochanter Regardless of the location of the fracture the upper portion of the nail must be sufficiently long to be well embedded in the neck and head fragments the distal end of the blade must extend down the shaft well beyond the level of the fracture in order to provide sufficient stability and fixation and obviate the use of external supportive measures.

Many features of treatment are common to this group of fractures As we proceed, variations in approach and technic will be described for each fracture. Since a great amount of maneuvering is unnecessary there are several advantages to immobilization on a fracture table, in contrast to draping the extremity and hip into the sterile field fewer assistants are required manipulation being reduced to a minimum the amount of trauma and shock is decreased maintenance of a more or less constant position means less variables, and facilitates the insertion of the guide pin roentgenograms may be made without disturbing or changing the position of the hip, without exposing the surgeon or his assistant to roentgen rays, and without contamination of the sterile field (Fig 80)

Careful preoperative preparation pays special dividends in this group of patients. The operation, particularly on the more distal and comminuted fractures of this group is of considerable magnitude. In obese or muscular individuals, exposure alone is rather traumatic, as the vastus lateralis muscle is split throughout the length of the incision, extensive periosteal stripping is necessary to expose fractures at the level of the lesser trochanter retraction of muscles incident to exposure creates considerable trauma. In comminuted fractures of this region, considerable maneuvering and traction may be required to restore all the fragments to their proper position. In young individuals, hemorrhage incident to the muscle-splitting incision and the stripping of the periosteum may be rather excessive and difficult to control. In the more proximal fractures, these problems are less serious, the conditions here being similar to those encountered in nailing of central fractures of the neck of the femur Chapter I deals with most of the features of the preoperative and postoperative care of these patients. Fractures of the hip should be nailed as soon as the patient s condition will permit, usually twelve to twenty four hours after injury

Technic of Internal Fixation of Trochanteric Fractures

Reduction of Fracture.—The patient is placed in the supine position with the buttocks resting on a cassette holder (Fig 80) Most of the intertrochanteric or basilar fractures of the neck of the femur may be anatomically replaced by the Whitman or Leadbetter maneuvers In peritrochanter or subtrochanteric fractures, both extremities are fastened to the foot pieces of the table and sufficient traction exerted to restore length and the normal neck-shaft angle. The affected hip should be abducted to only 150 or 160 degrees abduction beyond this degree will only cause angulation at the fracture site.

Anteroposterior and lateral roentgenograms are then made to ascertain the degree of reduction Ordinarily the anteroposterior view will show a quite satisfactory reduction if not, relatively minor adjustments of the amount of traction and the degree of abduction will correct any discrepancy The lateral view, however frequently shows the proximal fragment in a posterior or externally rotated position and in relatively poor contact with the distal frag

ment This separation of the fragments takes place as the extremity is r... rotated In comminuted peritrochanteric fractures and subtrochanter... tures, it is usually impossible to lock the surfaces sufficiently to bring b... ments anteriorly as one component i.e., the distal fragment rotates in... and brings the proximal end of the distal fragment into a rather pr... subcutaneous position the proximal fragment retaining its externally r... or posterior position Aside from basilar fractures of the neck of the... the poor position as seen in the lateral view does not necessitate remanip... of the fracture Ordinarily, the same position would be reproduced. In... any discrepancies in position are corrected under direct vision after ex... of the fracture

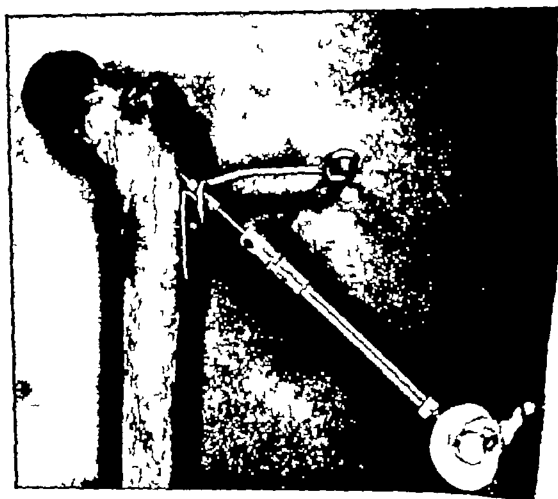


Fig. 314 —Nails for intertrochanteric fracture should be introduced at ... angle so that distal portion of blade will be flush with shaft. This is par... Jewett nail. Guide set at same angle as nail facilitates exact insertion.

Exposure —An incision is made over the lateral aspect of th... ning at the distal edge of the greater trochanter (p 179) The... be approximately one inch longer than the shaft portion of the n... is then carried down through the tensor fascia lata and vastus... to expose the trochanter and upper portion of the shaft. Bec... which the nail is inserted the skin incision is usually about... the exposure through the vastus lateralis muscle, i.e., the va... one inch proximal to the skin incision in its upper limb and the skin incision at the distal limb

In basilar fractures of the neck if the fragments have not been restored to their anatomic position the upper end of the incision may be extended into the lower limb of a Watson-Jones exposure (Fig 321) Through this exposure, the distal end of the proximal fragment may be lifted up into proper apposition with the trochanter with relatively little difficulty To expose the fractures properly at the level of the lesser trochanter the periosteum must be stripped from the shaft, and the anterior muscles must be retracted toward the midline. Maintenance of exposure is materially facilitated by the use of a Blount anvil retractor its edge being hooked around the shaft of the femur just below the lesser trochanter The distal limb of this incision may be extended as far as necessary for proper exposure

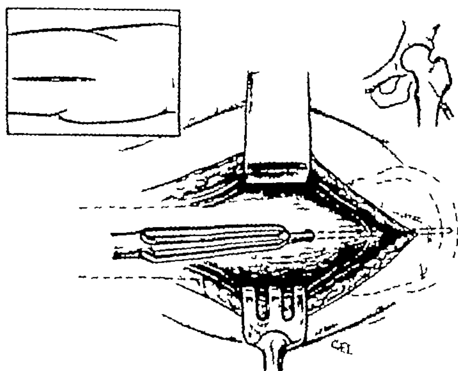


Fig 311 —Internal fixation of trochanteric fracture. Guide pin inserted through lateral aspect of femur position of pin and fracture checked by roentgenograms. Cannulated Henderson reamer inserted over guide pin provides hole in cortex for easy insertion of nail. Inserts show line of skin incision and position of pin in anteroposterior view

Insertion of Guide Pin.—Prior to the insertion of the guide pin, the following conditions should be fulfilled, as demonstrated in the roentgenogram (a) the normal angle between the head and neck in the shaft should be restored (b) as seen in the lateral view roentgenogram the head neck, and trochanter should lie in a horizontal or near horizontal plane with the fracture reduced (In subtrochanteric fractures, the position of the fracture itself may be temporarily ignored.) A horizontal, or near horizontal position is desirable for two reasons first if the extremity is externally rotated, the trochanter drifts so far backward into the buttocks that one finds himself working practically under the table second, one of the variables in inserting the guide pin is partially eliminated. An assistant at the foot of the table may readily ascertain whether the drill and guide pin are parallel with the floor if the guide pin is inserted mid-



Fig. 215.—Peritrochanteric fracture of femur. Eight months after internal fixation with Neufeld nail, fracture line is solid and lines of stress and strain have been re-established from function and weight bearing.

One might ask, 'Why use a guide pin?' In a large percentage of cases, *internal fixation could probably be secured without the insertion* of a guide pin. If the position of the nail is not correct, however the trouble incident to its removal and reinsertion will convince one of the desirability of more exact craftsmanship Removal and reinsertion of a guide pin which is improperly inserted is relatively simple repeated insertions of a nail, however, unnecessarily destroy bone in the neck and head as well as the cortex. This means less secure fixation. The use of a guide pin for trochanteric fractures is just as important as for central fractures of the neck of the femur and perhaps more so in that an additional factor has been added, i.e. the fixed angle of the nail requires that the angle of the guide pin be more exact



Fig. 314.—Comminuted subtrochanteric fracture. Medial fragment with lesser trochanter fixed to shaft by transfixion screws thereafter with *only tw fragments remaining fracture* reduced and fixed with Jewett nail.

The guide pin eliminates a lot of guesswork. From the anteroposterior and *lateral roentgenograms made after insertion of a guide pin*, one can (1) determine the proper length for the head and neck portion of the nail, (2) locate the nail in the proper position in the head, neck, and trochanter (3) determine whether the pin has been inserted at the same angle with the shaft as the fixed angulation of the nail, (4) stabilize the fracture site during the insertion of the nail. The last is not entirely necessary but, none the less, is desirable.

The technic of insertion of the guide pin is as follows a point is selected on the lateral aspect of the shaft of the femur midway between the anterior and posterior cortices of the femur and three-fourths to one inch distal to the bony excrescence of the greater trochanter from which the vastus lateralis muscle

the third fragment to either the proximal or distal fragment with a screw inserted in an anteroposterior or oblique direction followed by immobilization of the two main fragments by the blade portion of the nail (Fig 314) Fractures of the lesser trochanter are disregarded The bony attachment of the iliopsoas muscle may remain in a retracted position later, sufficient scar forms between the detached fragment and the shaft of the femur to provide efficient action of this muscle.

After Treatment.—The postoperative care of patients with intertrochanteric fractures without comminution or fractures of the basilar portion of the neck of the femur is essentially the same as for those with central fractures of the neck of the femur (p 448) As a rule the fracture is sufficiently solid at twelve weeks to permit partial weight bearing with crutches All restrictions are generally removed at sixteen weeks.

In comminuted peritrochanteric fractures and particularly comminuted subtrochanteric fractures, considerably more caution is necessary, depending upon the degree of fixation. Because of the extensive soft tissue surgery, active exercises are not begun until the wound is rather thoroughly healed. In the majority of cases, no external immobilization apparatus is utilized for the sake of comfort, however the extremity is frequently suspended in a balanced Hodgen's splint Rarely in the more distal and comminuted fractures, a cast is applied from the crest of the ilium to the toes.

FRACTURES OF THE NECK OF THE FEMUR

Internal fixation of this fracture by nail screws, and pegs is by no means a new procedure. The first report of this method of treatment was made by Langenbeck, in 1850 Successful results were reported by Nicolaysen and others prior to development of the roentgenogram. Thomas, in 1921, and Martin and King in 1922 reported excellent results following the use of steel wood screws for internal fixation At this time internal fixation was not uniformly successful nonelectrolytic metals were not available and, consequently absorption of bone and loss of fixation ensued. Inadequate roentgenographic control, inaccurate reduction or lack of dexterity on the part of the surgeon in introducing the material, rapidly brought the method into disrepute Smith Petersen is responsible for reviving and popularizing the procedure The present treatment of fractures of the neck of the femur was made practicable and efficient by the following (a) the development of efficient apparatus for internal fixation, particularly the Smith Petersen nail (b) the development of relatively inert non electrolytic metals subsequent to the experimental work of Venable, Stuck and Beech and (c) the perfection of efficient roentgenographic technic.

In the early stages the line of fracture in the neck of the femur was exposed and reduction and internal fixation were accomplished under direct vision (Fig 321) Since efficiency in nailing under roentgenographic control has been acquired, exposure of the neck of the femur in fresh fracture is not indicated unless the reduction is inadequate Internal fixation under roentgenographic control may be accomplished with a minimum amount of surgery and with minimum injury to the blood supply of the neck and head of the femur

Many types of apparatus have been devised for the purpose of internal fixation including the Smith Petersen nail the Johansson modification of the

arises. With a $\frac{3}{16}$ inch drill a hole is created at this point beginning at a right angle to the shaft and gradually angling the drill to a position of approximately 45 degrees. If the hole through the outer cortex is made considerably larger than the guide pin, fine adjustments of direction are possible with a minimum of effort. *Further there is considerable 'feel' as the guide pin is inserted.* Little or no resistance is encountered if the pin is properly directed. A guide pin is inserted into the drill 3¾ inches of the pin being allowed to protrude beyond the tip of the drill. The point of the guide pin is introduced through the hole in the outer cortex and directed so the plane in an anteroposterior direction is exactly 45 degrees with the shaft of the femur. A small guide may be simply constructed to provide this angle (Fig 310). An assistant at the foot of the table directs the surgeon to raise or lower the drill until the pin is parallel with the floor. The pin is then drilled into the head, neck, and trochanter until the tip of the drill approximates the cortex of the femur. Thereafter the drill is removed from the guide pin and roentgenograms are made to verify its position, length, and angle.

Insertion of the Nail.—Since 3¾ inches of the guide pin engages the neck and head, a study of the anteroposterior and lateral roentgenograms will quickly demonstrate whether a longer or shorter nail is necessary. Since some impaction occurs, it is more common to err on the long side. If the angle and the location of the guide pin are not relatively close to the desired position, the pin should be removed and reinserted. If a Jewett nail is used the guide pin should be relatively exact as the nail follows the course of the wire. If a Neufeld *nail is employed a slight degree of correction in angulation is possible, since* the V portion of the nail approximates the guide pin, but does not necessarily follow its exact course. In subtrochanteric fractures, an additional measurement is necessary to determine the length of the shaft portion of the nail. The shaft segment of the nail should project sufficiently distal to the fracture site to allow the insertion of at least three screws and preferably four screws into the shaft.

Assuming that the fracture and the guide pin are in proper position, one more thing must be done prior to the insertion of the nail. The lateral cortex of the femur is relatively fragile and brittle. To prevent splitting of the cortex, particularly in pertrochanteric fractures, a hole slightly smaller than the nail should be created in the lateral cortex. This is accomplished by the insertion of a cannulated Henderson reamer over the end of the guide pin. As the nail is driven into place, an assistant should steady the shaft portion so it will exactly parallel the shaft of the femur. When the nail is properly seated, the blade portion of the nail should be flush and in exact contact with the shaft. The blade portion of the nail is then affixed to the shaft of the femur by three or more screws. Usually these screws are relatively larger than those used for other long bones thus, a drill of proportionate size must be selected.

In subtrochanteric fractures, the position of the fragments may often be ignored until the nail has been driven into the neck trochanter fragment thereafter the distal fragment is properly aligned with the proximal one and the blade portion of the nail and held snugly in this relationship by the use of bone-holding forceps until the shaft has been transfixed with screws. If the shaft has been split obliquely producing a third fragment, rather than try to assemble all of these pieces at one time, the procedure is usually facilitated by fixation of

the third fragment to either the proximal or distal fragment with a screw in serted in an anteroposterior or oblique direction followed by immobilization of the two main fragments by the blade portion of the nail (Fig 314) Fractures of the lesser trochanter are disregarded The bony attachment of the iliopsoas muscle may remain in a retracted position, later, sufficient scar forms between the detached fragment and the shaft of the femur to provide efficient action of this muscle

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Many types of apparatus have been devised for the purpose of internal fixation including the Smith Petersen nail the Johansson modification of the

Smith Petersen nail, the Austin Moore pin, the Knowles pin, the Henry screw and the Henderson lag screw Valls, Cubbins, Lippman and Thomson have also devised pins, nails and screws for fixation purposes. In the hands of the originators of these pins and nails, each seems efficient. In the vast majority of cases, we have found the Smith Petersen nail to be eminently satisfactory The multiple pin method however, is at times preferable. The indications for the use of multiple pins will be described later

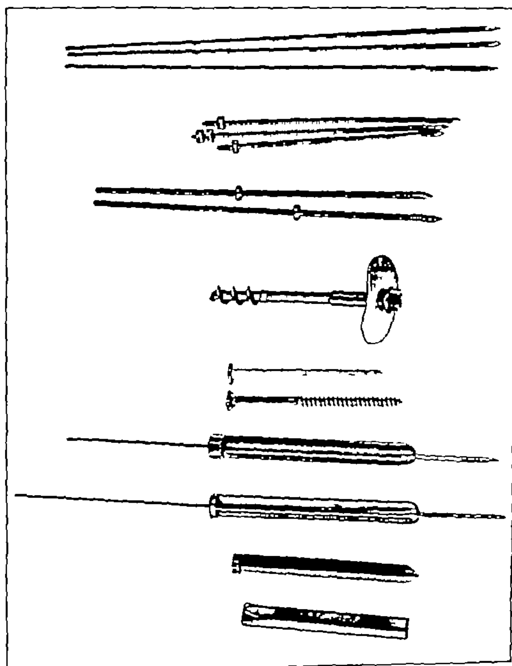


Fig. 314.—Materials for internal fixation of fractures of neck of femur, in order: Original Smith-Petersen nail, Vitallium nail, Johansson modification of Smith-Petersen nail, Smith-Petersen nail with larger central tunnel for reception of larger guide wire, Martin screw plain, Vitallium nail, Henderson lag screw Knowles pins, Moore pins, and Gaenslen spikes.

Numerous variations of technic and many mechanical gadgets for directing the guide wire have been suggested. In our early experience, we utilized the Engel May device, but soon found that this was unnecessary and even undesirable. No originality is claimed for the technic to be described. It evolved over a period of ten years and contains features common to several technics.

In fractures of the neck of the femur, many questions arise in which both the patient and doctor are mutually interested (1) What are the chances of survival? (2) Will the bone grow back together? (3) What are the chances of walking again? (4) Will there always be some pain in the hip?

Accurate answers to these questions can be obtained only by a careful analysis of a long series of cases. Boyd and George, in 1947, surveyed approximately 300 *consecutive fractures* of the neck of the femur which were treated by the staff at the Campbell Clinic The total mortality of the 300 patients was 9.3 per cent 28 *deaths occurred* 21 within the first four weeks and 7 between one and six months All the patients who died were sixty years of age or over The mortality increased rapidly *with each decade, reaching 25 per cent in patients* in the ninth or tenth decade

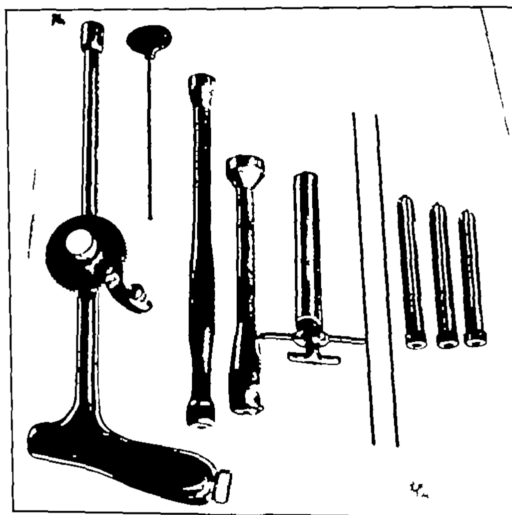


FIG. 317.—Instruments for insertion of Smith-Petersen nail: Drill, special drivers, extractor guide pins, and three sizes of Smith Petersen nails, differing ¼ inch in length, i.e., 3½ to 4 inches.

One hundred thirty-one patients were followed less than a year One hundred forty-one were followed for one year or longer Bony union took place in 86.5 per cent of the hips. In this study and the study of aseptic necrosis and arthritic changes only the patients who were followed for at least one year were included. Of the 19 fractures which failed to unite poor reduction inadequate mechanical fixation, premature removal of the nail or a combination of these

factors contributed to the nonunion Nine of the ununited fractures followed satisfactory reduction and nailing Two of these were patients with Paget's disease involving the head and neck of the femur Thirty three and six tenths per cent of the patients developed aseptic necrosis, this complication being apparent in roentgenograms before the lapse of two years in every case. Most of the patients with aseptic necrosis had arthritic changes, a small number did not have aseptic necrosis, yet had varying degrees of arthritic change in the hip. According to these figures, the average fracture of the neck of the femur has the following prognosis mortality 9 3 per cent, poor end result incident to nonunion and severe arthritic change 28 1 per cent, a fair end result based on moderate arthritic change, 19 per cent a good end result 43 6 per cent. From this study in 86 5 per cent of the cases, the prospect of obtaining union is favorable

In the above review, Boyd and George did not include impacted fractures of the neck and head (Pauwel's type I fractures) or basilar fractures of the neck. The prognosis in these fractures is much more favorable than that of Pauwel's types II and III fractures.

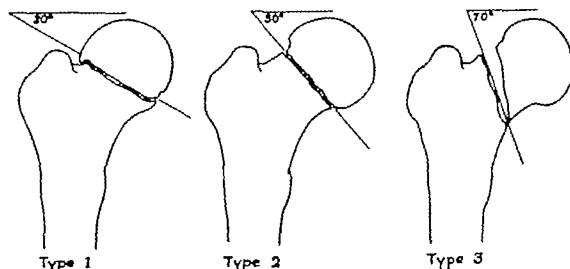


Fig. 314—Pauwel's classification of fractures of neck of femur according to angle of inclination.

A great deal has been written about the high incidence of nonunion in Pauwel's type III fractures. This is attributed to the shearing force at the fracture site because of the angle at which the fracture occurred. The percentage of nonunion in Pauwel's type II was 16.5 per cent. The percentage of nonunion in Pauwel's type III was 10 8 per cent. The latter group of course, was considerably smaller than the first group The difference in those percentages suggests that, with adequate internal fixation, the shearing force at the fracture site is probably eliminated. The broader fracture surfaces tend to unite more readily

The incidence of aseptic necrosis was higher in our patients with nonunion than those with union having been 60 per cent in the former and 38 per cent in the latter Although aseptic necrosis of the head of the femur is a definite factor in nonunion it does not necessarily preclude union. Of approximately

149 hips wherein union was obtained 15 or 10 1 per cent showed absorption of the neck of the femur to the extent of 1 cm or more This indicates that absorption of the neck itself does not preclude union provided the type of fixation employed will allow the nail to extrude gradually, thus maintaining contact between the head and neck at the fracture site. This is a definite argument against the use of pins which are threaded throughout their entire length or the use of transfixion screws at the base of a Smith Petersen nail to prevent its extrusion A fixation instrument which will allow this settling to take place is obviously advantageous otherwise, the fragments will be held apart

Prior to the development of internal fixation, the mortality rate was high Fewer patients obtained union a study of the complications which might eventually arise with union received little attention These problems, which are concerned largely with arthritic changes following bony union now come to the forefront We do not attribute arthritic changes to the use of internal fixation itself but to the fact that a larger number of patients survive and obtain union It is obvious that arthritic changes following bony union gradually increase in number and severity with time and use thus, severe arthritic changes develop in approximately one-third of the patients followed two years or longer In fact the number of patients who develop severe arthritic changes will now exceed the number with nonunion In the future, therefore, the development of methods of treatment for the severe arthritic changes will constitute the problem associated with this fracture The problem of nonunion will assume less and less importance, so far as the number is concerned.

Although the above figures may appear discouraging, the advantages of internal fixation lie in the fact that the mortality is lower the patient is more comfortable, medical complications are less common, the incidence of senile psychosis is materially reduced the cost of hospitalization is less, and the prospects of bony union are far better than those of methods previously employed

Aside from incomplete fractures, internal fixation is indicated in all fractures of the neck of the femur Impacted fractures are nailed without disturbance of the impaction, provided the position of the fragments is satisfactory a neutral or valgus relationship of the head and neck is acceptable With a varus position, the impaction is broken up completely and the position changed by manipulation. Basilar fractures of the neck are treated as intertrochanteric fractures (p 426)

Technic of Internal Fixation of Fractures of the Neck of the Femur

Method of Reduction.—With the patient in a supine position on a fracture table and the normal extremity affixed to the foot stirrup an assistant steadies the pelvis. The hip and knee are flexed to 90 degrees, and the hip is rotated to break up any slight degree of impaction. Traction is exerted in a vertical plane until the normal length is regained and the neck engages the head. At the same time, the extremity is abducted, extended, and internally rotated, locking the head in position with the neck. The foot is then affixed to the foot stirrup with the extremity in 160 degrees of abduction, a neutral position so far as extension and flexion are concerned, and sufficient internal rotation to bring the patella to an upright position This amount of internal rotation usually places the head neck and trochanter in a horizontal plane Roentgenograms

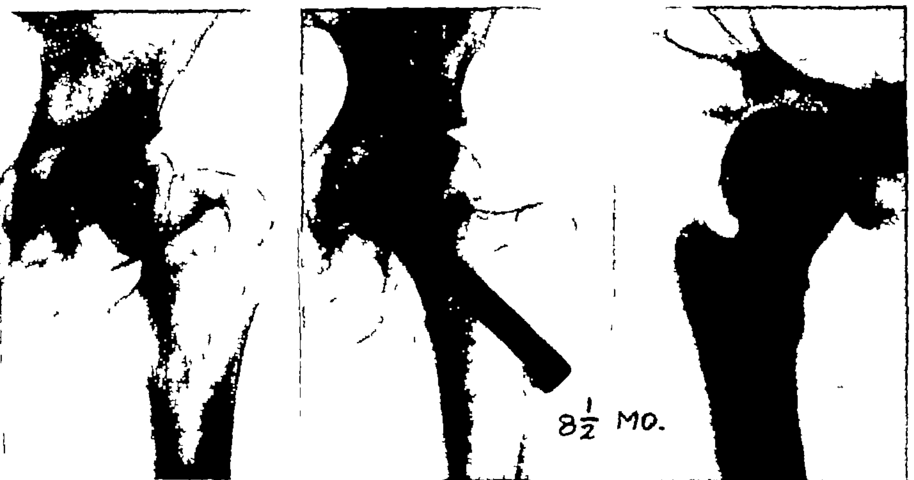


Fig. 319.—Aseptic necrosis of head and arthritic changes in joint are most common postoperative complications of fractures of neck of femur. Pauwels type-I fracture at eight months; union is solid and head apparently viable.







Fig. 320.—Same as Fig. 319 Increasing incongruity of articular surface of head of femur with advanced arthritic changes secondary to aseptic necrosis of head at 2 years, 2¾ years, and 3½ years.

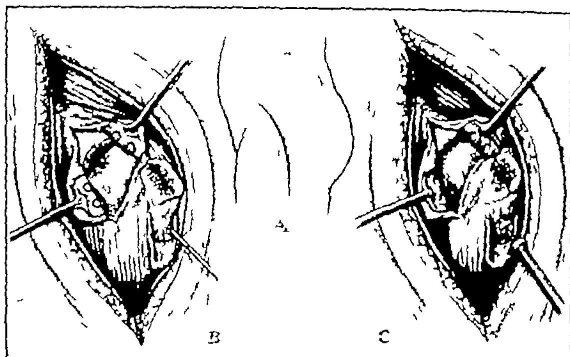


Fig. 321.—Open method of insertion of Smith-Petersen nail, Watson-Jones technic. *A*, Watson-Jones incision. *B* Exposure of fracture site and insertion of guide pin through proximal fragment to center of fractured surface. *C* Reduction completed guide wire inserted into proximal fragment nail inserted over guide wire.

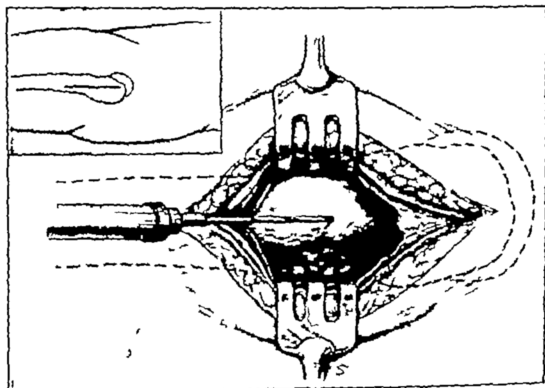


Fig. 322.—Insertion of Smith-Petersen nail by blind method. Insert shows line of incision over trochanter and upper portion of shaft. Drill hole through femur ¾ inch distal to trochanter or vastus externus line, in anticipated direction of guide pin.

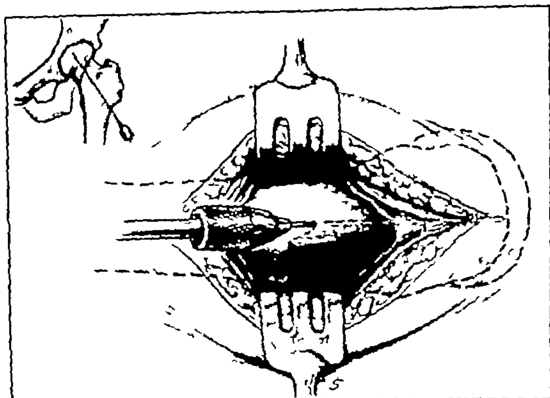


Fig. 323.—Same as Fig 322. Guide pin inserted to within ¼ inch of articular surface of head of femur Checked by roentgenograms in both lateral and anteroposterior planes.

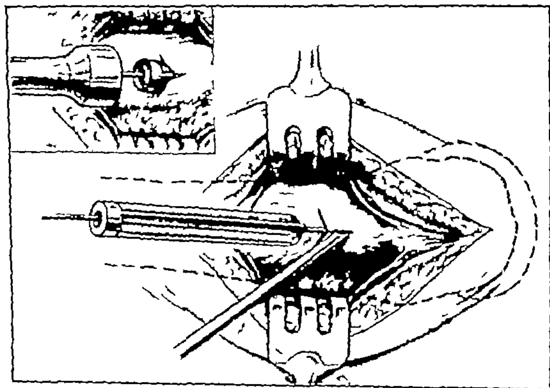


Fig. 324.—Same as Fig. 322. Small cuts with chisel expedite insertion of nail through outer cortex. Nail of proper length inserted over guide pin and driven into position with special driver

are then made in the anteroposterior and lateral planes. While the films are being developed, the operative field is prepared but not draped.

The first requisite to a satisfactory operation is restoration of the anatomic position of the fragments as nearly as possible In the lateral view only the slightest variation from the normal is permissible. In the anteroposterior view a neutral position, or a slight valgus relation of the head and neck is necessary Any variation from these rather rigid requirements demands that the hip be manipulated until the position is satisfactory In the vast majority of cases, the first maneuver will be successful. The necessity for remanipulation of a fracture of the hip need not be embarrassing occasionally a fracture plagues even the most dextrous operator

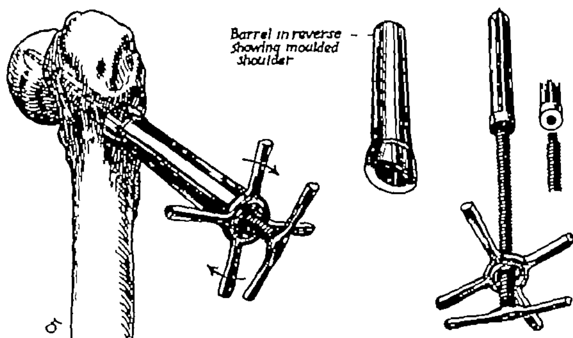


Fig. 325 —Special extractor for removal of Smith-Petersen nail.

If the position is not adequate after the second attempt, reduction must be accomplished under direct visualization through a Watson-Jones approach (Fig 321) Frequently this possibility can be anticipated preoperatively comminuted fractures, Pauwel s type III or fractures with a goose-neck, Z-step, or serrated edges may cause difficulty Inability to fit a ledge or serrated margin into its contiguous defect may be due to interposed soft tissue. Instead of a pedunculated flap the sharp edge of the anterior or superior margin of the neck may engage the intact capsule with manipulative measures, the capsule becomes more tightly impaled and impinges between the fracture surfaces, precluding proper apposition

Method of Taking Roentgenograms.—The use of a cassette holder for the anteroposterior view (Fig 80) and a curved casette for the lateral view obviates many difficulties. Roentgenograms may be made in both planes without disturbing the condition of the extremity or contaminating or disturbing the drapes. The surgical team is not exposed to the roentgen rays. Three sets of roentgenograms are necessary The first is made immediately after the reduction but prior to preparation of the hip the second, after insertion of the

guide pin, and the third after insertion of the nail Additional sets are made as required (Twelve or fourteen sets of routine exposures may be made without inducing any roentgen ray changes in the skin) The first and third set of roentgenograms do not prolong the operative time, the hip may be prepared before operation and the wound sutured after operation while the films are being developed For the second set, there is a five-minute delay The time required for developing the films is contingent upon the use of a concentrated developer and hypo at a temperature of 70 to 72 degrees. The developing room should be close to the operating room Since bone detail is unnecessary, the films may be slightly overshot and underdeveloped The success of internal fixation by roentgenographic control is dependent upon the efficiency of a well trained roentgen ray technician.

Draping —On the lateral aspect of the hip, the operative field is "squared" by the proper number and thicknesses of drapes Towel-clips are placed so as not to be superimposed on the fracture in the roentgenograms. For the same reason, stockinet is sutured to the edges of the skin wound in preference to the use of metal skin-clips. An L-shaped frame over the lower end of the table permits easy access to the curved cassette (Fig 82)

Exposure —Through a lateral incision three to four inches in length, the lower edge of the greater trochanter and the upper two inches of the shaft of the femur are exposed (p 179)

The Use of the Guide-Wire —A point is selected on the lateral aspect of the shaft of the femur, midway between the anterior and posterior cortices and three-fourths to one inch distal to the bony excrescence of the lower edge of the greater trochanter from which the vastus lateralis muscle originates. At this point a hole $\frac{3}{16}$ inch in diameter is drilled in the lateral cortex of the femur in a slightly oblique direction. The hole is considerably larger than the guide pin, thus permitting fine adjustments in direction of the guide pin and allowing a sense of ' feel ' as the guide pin penetrates the neck and head. A guide pin is then inserted into a chuck drill a predetermined amount of the wire, usually 3½ or 3¾ inches, being allowed to protrude from the end of the drill. The guide pins are highly tempered steel rods 2.5 mm. in diameter and 8 inches in length. Scored or bent guide pins should be discarded, otherwise, the nail may engage and drive the wire into the pelvis The pointed end of guide pin is inserted into the hole as the operator places the drill at a 45-degree angle with the shaft of the femur If the lateral view shows a horizontal position of the head neck and trochanter, an assistant at the foot of the table directs the surgeon to raise or lower the drill until the guide wire is parallel with the floor The wire is then drilled into the neck and head until the tip of the drill touches the cortex. The guide pin should encounter little resistance as it traverses the neck, and slight resistance as it traverses the fracture site and the cancellous center of the head of the femur Undue resistance usually means that the end of the wire is traversing either the cortex of the medial portion of the shaft of the femur or one of the cortices of the neck of the femur Roentgenograms are made in the anteroposterior and lateral planes to confirm the position of the pin The ideal position is the exact center of the neck and head. The guide pin should be drilled in slowly, rather than pushed into position otherwise, when the pin is off line particularly if reduction is unstable the head may be forced into an un

desirable position A slightly off-center position in a posterior or distal direction *may be acceptable If the guide pin is in a proximal position in the neck,* the head may be tilted into an undesirable varus position when the nail engages the head or, postoperatively the nail may gradually be forced out of the head on adduction movements. In the lateral plane, if the wire is anterior to the central point, only a slight quadrant of the head is engaged by the nail and external rotation movements may disengage the nail from the head, with subsequent loss of fixation. Slight variations in angulations of the guide pin from the normal neck shaft angle are permissible provided the pointed end of the guide pin is in the exact center of the head of the femur



Fig 326.—If reduction is unstable, multiple pins are used in preference to a Smith-Petersen nail their removal, incident to poor position of the pins, or tilting or displacement of
the head, is easier than removal and insertion of a Smith-Petersen nail. *A* Unsatisfactory
reduction after first attempt, corrected by second maneuvers. Reduction in lateral view satis-
factory after both attempts. *B* Guide pin purposely inserted through head into ilium. Satis
factory position of pin in A P view but distraction at *fracture*. In lateral view pin is satis-
factory position in neck fragment, but engages head in anterior quadrant, tilting it posteriorly

Since a predetermined length of the guide pin is engaged in the head and neck, it is a simple matter to determine whether the proper length nail is more or less than this predetermined length If inadvertently, the pin should slip in the chuck and one is in doubt as to its length, the amount of pin which protrudes from the shaft of the femur may be measured with a ruler This is subtracted

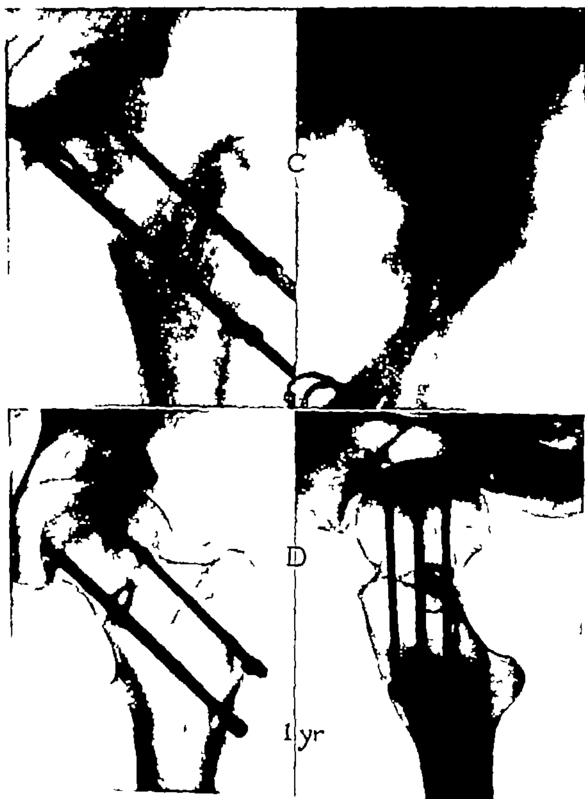


Fig. 327 —Same as Fig. 326 C Fracture adequately stabilized by four parallel Knowles pins. Angling or fanning of pins to increase stability is undesirable. With absorption of neck, parallel pins allow telescoping of fragments. D Solid union, good position one year after fracture

from the total length of the pin (eight inches) and, thereby determines the amount in the head and neck

If the fracture is unstable, a second guide pin may be inserted one-fourth inch distal and parallel with the first guide pin, to steady the head and prevent displacement as the nail is driven into place In Pauwel s type III fractures, wherein a long, pointed spicule of bone is present on the inferior aspect of the neck fragments, angulation of the neck is likely for this reason, multiple pinning may be preferable

If open reduction is necessary because of inability to reduce the fracture, or loss of reduction on insertion of the guide pin control of the head fragment may be difficult Boyd drills a Knowles pin into the head, using this as a lever to maintain proper rotation and apposition until one or more guide pins have been inserted from the lateral aspect of the trochanter across the fracture.

Insertion of the Nail.—*The nail should be of sufficient length to penetrate* the head of the femur within one-eighth to one-fourth inch of the articular sur face, while the base of the nail thoroughly engages the lateral cortex of the shaft. The cannulated portion of the nail should be checked by running a guide pin through it before it is driven into the femur The cannulated por tion of the nail is threaded on the guide pin and approximated to the cortex of the femur If the cortex is particularly dense necessitating an added precau tion, small grooves corresponding with the flanges of the nail may be cut in the cortex with a chisel A driver with a tunnel in the center is next threaded over the wire and the nail is driven into the femur by means of a heavy mallet (Fig 324) The driver must be parallel with the nail and must be struck direct blows with the mallet otherwise the cortex may be split. With each half inch progression of the nail the relation of the nail and guide pin should be checked as a precaution against penetration of the guide pin into the pelvis. After removal of the wire, the driver is placed over the trochanter and tapped a few times with a mallet in order to impact the fragments A final set of roentgeno-grams is made to check the position of the nail. If, by mistake, the nail is in serted through the articular surface, a special instrument is applied (Fig 325) and the nail is withdrawn to the desired position or a shorter nail inserted.

Insertion of Multiple Pins.—For fixation of an impacted fracture under *local anesthesia*, three Knowles pins are *preferable to a Smith Petersen nail.* The noise and violence attendant upon the insertion of a Smith Petersen nail is likely to be rather terrifying to a conscious patient.

In an extremely oblique or unstable fracture, multiple pins, as Knowles pins, are desirable in that their removal and insertion incident to any tilting or displacement of the head is far more simple than removal and insertion of a Smith Petersen nail. The pins are inserted in much the same manner as the guide pin as a rule, three or four are required. They are inserted in a *more or* less quadrangular pattern the proximal end of the quadrangle being in the re-gion of the center of the head of the femur

After Treatment.—Immobilization by any form of external fixation ap-paratus is unnecessary and in fact undesirable Passive flexion and extension of the hip and knee are undertaken on the second day Elderly patients are usu ally allowed up in a wheel chair on the second postoperative day Frequent changes in position are encouraged. As soon as the pain and soreness *of the in*

cision subsides, active movement, particularly quadriceps set up exercises is instituted By the end of the second week, the patient should be able to raise the heel off the bed unassisted while the knee is held straight. Extremes of adduction and abduction movement are to be avoided Patients who are relatively agile are allowed to get out of bed and into a wheel chair unassisted, bearing the weight on the unaffected extremity Walking with crutches is not encouraged until twelve weeks have elapsed from the date of the fracture, this depends upon the status of the hip as determined by roentgenograms at that time Partial weight bearing is usually allowed at sixteen weeks In the majority of cases, union is sufficiently firm at six months to permit walking without support

Infections Following Internal Fixation of Fractures of the Neck of the Femur

Infections following the insertion of internal fixation for fractures of the neck of the femur present many problems peculiar to this condition The common practice of giving penicillin to elderly patients postoperatively as a prophylactic measure or its use in any febrile condition of undetermined origin adequately controls the systemic manifestations of a low-grade infection in the hip joint. On the contrary the local infection may simmer at a low ebb indefinitely and produce considerable damage before the gravity of the situation is realized. We have observed two cases wherein a low grade osteomyelitis had eroded the edge of the acetabulum, permitting a subluxation of the head from the hip joint. Roentgenographically, these cases resemble congenital subluxation of the hip Late stages of infection are exhibited by multiple draining sinuses about the trochanter septic sequestration of the head of the femur with nonunion, and a fixed adduction contracture As a consequence of the chronic sepsis, the patient loses weight, becomes anemic and, if the chronic sepsis persists, may die of a generalized amyloidosis.

Kellogg Speed has summarized the treatment as follows (1) early recognition of the infection and identification of the organism, (2) institution of measures to improve the patient s general condition in preparation for a rather extensive surgical procedure (3) the insertion of skeletal traction into the tibia for comfort's sake, to prevent deformity, and to facilitate the handling of the patient. The metallic fixation should be extracted, the head of the femur removed from the acetabulum and the neck replaced in the acetabulum in a manner similar to that of the Whitman reconstruction procedure. Continuous drainage should be insured by the insertion of a petrolatum gauze drain Thereafter the hip should be immobilized in a plaster cast until sinuses are healed.

FRACTURES OF THE NECK OF THE FEMUR IN CHILDREN

Fractures of the neck of the femur in children carry a poor prognosis. Avascular changes in the head of the femur deformity, nonunion limited motion, or growth disturbances may follow In the majority of cases reported in the literature the Whitman abduction method with traction was employed.

Of Wilson s series of ten patients, eight of whom were followed for a sufficiently long time to determine the end results only two had good function

Of twelve patients treated by Carrell and Carrell, one-third developed an aseptic necrosis of the head of the femur

It seems probable that treatment similar to that described for slipped upper femoral epiphysis might offer some improvement over these rather discouraging results, particularly of the cervicotrochanteric type of fracture Multiple pins of proper length may be inserted across the fracture site to provide relatively stable fixation without violating the epiphyseal cartilage We have treated one such fracture successfully Reports of the use of internal fixation are too few to permit any definite conclusions. Certainly the prognosis should be guarded, regardless of the location of the fracture or the method of treatment.

Carrell and Carrell suggest that fractures observed in a coxa vara position after four weeks should be permitted to unite in an effort to prevent a rather certain aseptic necrosis. The deformity may be corrected later by osteotomy

FRACTURES OF THE PELVIS

With the exception of fractures of the acetabulum associated with central dislocation of the hip (p 298) fractures of the pelvis may be treated successfully by closed methods. *Even in the presence of such extensive injuries as* separation of the symphysis pubis, with a fracture of the ilium or a dislocation of the sacroiliac joint, an adequate relationship is ordinarily restored. In rather gross displacement or even in nonunion of one or more rami of the pubis disability is usually relatively slight. A rare case may necessitate surgery and replacement and realignment of a segment of the pelvis (Figs. 328-329)

LUMBAR AND DORSAL SPINE

The vast majority of fractures of the lumbar and dorsal spine are treated simply by routine hyperextension methods. Exceptions are (1) fracture or fracture-dislocation, associated with cord injury (2) fracture-dislocation or dislocation with interlocked articular facets (3) fracture of the posterior wall of the body of the vertebra, the central portion bulging into the vertebral canal (4) fracture of the pedicles or pars articularis, with spondylolisthesis (5) hyperextension fracture

The details of surgical treatment of the first two of this group will be described. For fractures of the posterior wall of the body of the vertebra Rogers advises fixation by plaster without hyperextension until union is complete at approximately four months He describes one case wherein a late neurologic complication necessitated laminectomy and fusion Fractures which interrupt the posterior neural arch particularly the pedicles, may at times require fusion if bony union is not complete. Hyperextension fractures are treated by conservative methods.

FRACTURES OF LUMBAR OR DORSAL SPINE WITH PHYSIOLOGIC BLOCK OF THE CORD

In this condition all treatment is directed toward relief of pressure on the spinal cord Correction of angulation and displacement of the vertebra may suffice. In the presence of a complete or partial physiologic block, and a fluid block, as indicated by a positive Queckenstedt test laminectomy should be under



Fig. 328.—Separation of symphysis pubis with 1¾ inch displacement, associated with *fracture of the ilium just* above acetabulum with *one* inch medial displacement and rotation. Reduction unsuccessful by all conservative means.



Fig. 329.—Same as Fig. 328. Four years after open reduction and wiring of symphysis pubis, patient has no disability except slight discrepancy in length.

taken, even though roentgenograms demonstrate an apparent displacement of the vertebra, indicating severe compression or severance of the cord. The efficiency of laminectomy is debatable, however if the injury is followed immediately by a physiologic block. Preferably, the operation was performed at once, since the patient is practically never in surgical shock unless other injuries are associated.

The Queckenstedt test is not infallible, since the response may be normal if only a small fragment of bone is pressing on one portion of the cord. Further the roentgenogram may show only moderate displacement of the vertebra, while the cord is completely severed or, the cord may remain intact in the presence of severe angulation of the vertebrae Despite these possible sources of error few unnecessary operations will be performed if the results of the Queckenstedt test and the roentgenograms are properly evaluated.

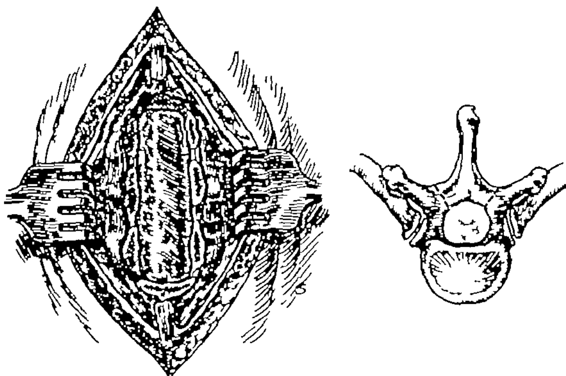


Fig. 339 —Laminectomy for fractures of the spine with physiologic block of the cord. Insert shows amount of bone removed.

Technic of Laminectomy—A curved incision five inches in length is so placed that its center will be over the affected vertebra. Two spinous processes proximal and distal to this vertebra should be exposed. To prevent hemorrhage, the soft tissues are stripped subperiosteally from the spines and laminae. On the fractured process, sharp dissection is used rather than blunt dissection in addition the fragment should be grasped with an instrument and constant traction applied in such direction as to protect the cord. The spine and laminae are removed with rongeurs to within a short distance of the articular facets. The lamina above or the one below or both, are also resected if pressing on the cord. Adequate exposure and perfect hemostasis should be obtained before the dura is opened After incising the dura, subdural hemorrhagic clots are removed and the cord is inspected through the arachnoid. If amply justified, the cord may be opened Dislocations or displacement may be reduced at this time by traction and manual force.

After Treatment.—The patient is placed on a Bradford frame covered with an air mattress. The utmost care must be enforced to prevent respiratory, abdominal and urinary complications, and expert nursing attention is necessary to prevent the development of decubital ulcers.

The prognosis of spinal cord injuries is always doubtful and frequently discouraging. As the operative risk from laminectomy is negligible, however, particularly in the lower portion of the spine, the procedure is worthy of trial if there is the slightest possibility of material relief.

DISLOCATION OR FRACTURE-DISLOCATION OF THE LUMBAR SPINE

Rogers, Adams, and Munro and Irwin report cases of fracture-dislocation treated by open reduction. Rogers sums up the treatment as follows: Prior to any treatment, roentgenograms must be made to demonstrate whether or not the articular facets are fractured. If the processes are intact, their relationship must be determined. Open reduction is indicated if the processes are overlapped or are likely to lock on hyperextension. If the forward displacement of the superior vertebra is associated with lateral or rotary displacement of the articular facets, open operation unquestionably offers the safest means of reduction.

This is a dangerous group of injuries. Treatment must therefore be carried out cautiously, otherwise the cord or cauda equina may be damaged or the existing injury may be aggravated.

Spanger points out that, if a dislocation is in the lower thoracic region, displacement is likely to be only minimal, as the obliquity of the spinous process limits the amount of displacement unless it is fractured. Ordinarily the articular facets will be found tip to tip, and reduction may be accomplished with relatively little manipulation and trauma. In the lumbar region, however, true interlocking occurs.

Technic of Open Reduction.—Through a three-inch curved incision, its center over the area of the dislocation, the spinous processes are exposed. The muscles are separated subperiosteally from the spinous processes and laminae, and the extravasated blood is removed. If necessary the superior spinous process may be excised at its base to provide better access to the two superior articular facets. In a case of complete separation of the articular facets and a rotary and lateral deformity, Rogers succeeded in reducing the dislocation by the following means: After freeing the articular facets, the spine was carefully flexed by lowering the ends of the operating table. The vertebra was then rotated into alignment with a periosteal elevator and hyperextension accomplished the reduction. If the articular facets are overlapped, Munro and Irwin employ the following procedure: one of the superior articular facets of the inferior vertebra is removed; thereafter an assistant attempts reduction by hyperextension of the spine. Should this fail, facetectomy is carried out on the opposite side (in such a case it would seem advisable to augment this procedure by a *rather hasty* fusion and a Rogers-type wiring).

After Treatment.—To maintain the hyperextended position, the patient is placed in a previously prepared plaster bed. Each leg is supported on a Braun splint. Subsequent treatment depends upon the presence or absence of damage to the cord.



Fig. 331.—Open reduction of dislocation of lumbar spine (case of W. A. Rogers). Appearance of lateral articulations after exposure. (From Rogers, W. A.: J. Bone & Joint Surg. 20: 689, 1938.)

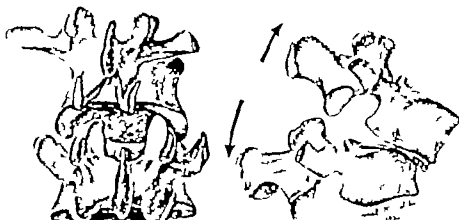


Fig. 332.—Same as Fig. 331. Flexion disengages articular processes. (From Rogers, W. A.: J. Bone & Joint Surg. 20: 689, 1938.)

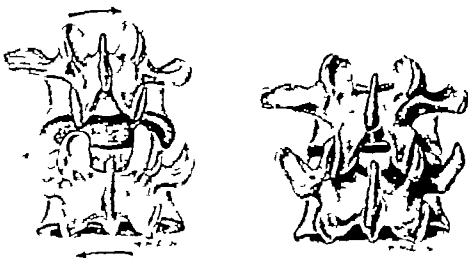


Fig. 333. Fig. 334.

Fig. 333.—Same as Fig. 331. Rotation realigns displaced articular processes. (From Rogers, W. A.: J. Bone & Joint Surg. 20: 689, 1938.)

Fig. 334.—Same as Fig. 331. Reduction completed by extension. (From Rogers, W. A.: J. Bone & Joint Surg. 20: 689, 1938.)

CERVICAL SPINE

Trauma of the cervical spine may produce a wide variety of lesions varying from dislocations without fracture to massive fractures without dislocation Frequently, both a fracture and a dislocation are sustained Dislocations vary from mild degrees of spontaneously reduced subluxation to complete overlapping of the articular processes. Fractures associated with dislocation vary from small chip fractures of the inferior border of a vertebra to complete separation of the pedicles, fractures of the articular processes, or marked compression fractures of the body The milder lesions, such as crush fractures or compression fractures of the bodies of the vertebrae or subluxation of the articular processes, respond satisfactorily to simple measures, namely, traction, hyperextension, and immobilization in plaster followed by a brace In more severe injuries the treatment becomes correspondingly complicated difficult, and perhaps dangerous For the purposes of discussion operative treatment will be applied to dislocations as one group and to fracture-dislocations as another group

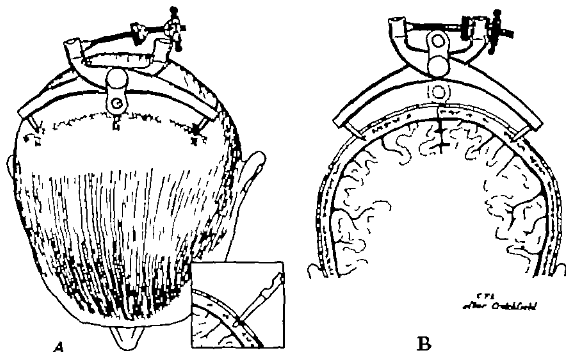


Fig. 335.—Crutchfield tongs for skeletal traction of cervical spine following fracture-dislocations. Insert shows special drill with flange to prevent penetration of inner table of skull. *A* Proper position for application of tongs center of tongs in midline in lateral plane, tongs are in line with mastoid tips. *B*, Application of tongs completed. (Redrawn from Crutchfield, W G Am. J Surg. 38, 592, 1937)

As a rule following dislocations of the cervical spine and the attendant injury to the intervertebral disc, the intervertebral space between the involved vertebrae will become narrowed over a period of years with the formation of osteophytes or spurs anteriorly and posteriorly In some cases, fortunately, the intervertebral space may be completely bridged fusing the bodies of the vertebrae.

Skeletal Traction for Fractures or Fracture-Dislocations of the Cervical Spine

In many lesions, the application of skeletal traction followed by conservative measures may be the only treatment necessary For the more severe lesions, skeletal traction is practically always an integral part of the more radical treatment.

Crutchfield has described the use of skeletal traction in both recent and old fracture-dislocations of the cervical spine. For this purpose, he devised a *special type of tongs, which are extremely efficient, particularly from a nursing standpoint.* The tongs are applied to the vertex of the skull.

Everyone recognizes the potential complications from the institution of skeletal traction to the skull, yet the condition for which such traction is applied justifies the risk. Skeletal traction may be employed not only in fresh fracture-dislocations with or without cord injury but is also applicable to a group of cases which are difficult to treat, namely, old fractures or fracture-dislocations of the cervical spine wherein inefficient treatment or none at all was given at the time of the original injury. Crutchfield states that in this latter group even after bone-productive changes are demonstrated, relief of symptoms through partial reduction or disimpaction of the fracture may be obtained by the use of skeletal traction, thus eliminating the necessity for open reduction or section of the sensory roots. The tongs are inserted by the following procedure.

Technic (Crutchfield).—*After proper preparation of the patient's head,* lines are painted on the scalp in the midline of the skull and the approximate plane of the cervical articulations (in line with the mastoid tips). These lines will aid in the proper placement of the tongs. With the traction bar resting on the midline the tongs are bent down upon the transverse line and the points of contact marked for the placement of stab wounds. *After injection* of novocain, stab wounds just large enough to admit a drill are made down to the skull. A special drill point with a flange at the distal end allows the drill to penetrate only the outer table of the skull: in children, the depth is 3 mm.; in adults 4 mm. The points are now fitted into the bony perforations and held in position until the tongs have been locked. The stab wounds are dressed with a collodion dressing. Each morning the skull tongs must be checked and, usually, tightened. Even so, the tongs may pull out of the skull after traction has been constantly in force for as long as two weeks.

DISLOCATIONS OF THE CERVICAL SPINE

The most common site of dislocation is between the fifth and sixth cervical vertebrae. If the articular processes are overlapped and locked on both sides, a partial or a complete physiologic block of the cord is usually associated and the prognosis is grave. In unilateral dislocations, wherein the inferior articular process of the superior vertebra rides upward, over and forward upon the superior articular facet of the inferior vertebra, neurologic manifestations, such as a partial paralysis of the arm and sensory deficits, may be associated. These changes, however, are usually temporary and recovery may be anticipated.

Prior to any manipulative procedure, it is essential that roentgenograms be made and studied to ascertain the presence of any fracture. The discovery of a small chip fracture of the anterosuperior border of the inferior vertebra is the rule, rather than the exception. This lesion is not significant and has no bearing upon the treatment. The presence of even fine linear cracks through the pedicles, articular processes, or the pars articularis, or the presence of a crushing *injury to* the body of the inferior vertebra, however, should cause one to proceed cautiously.

In the presence of a dislocation uncomplicated by a fracture of any consequence one may employ either of two closed methods of treatment (a) immediate manipulative reduction of the dislocation under general anesthesia, (b) immediate or gradual reduction of the dislocation by means of skeletal traction Ordinarily it is our policy to adhere to the slower more conservative, and less dangerous method of skeletal traction without general anesthesia

Reduction of Dislocation by Manipulation

Many orthopedic surgeons prefer general anesthesia with immediate reduction Ordinarily, this maneuver consists of the Walton technic, or some modification thereof Eastwood observes that reports in the literature do not bear out the contention that catastrophic neurologic complications are common with this maneuver It is his opinion that if one uses reasonable care, no serious neurologic complications will arise Conwell also states that, in simple unilateral and bilateral dislocations of the cervical spine, immediate reduction by manipulation is the procedure of choice In unilateral cases he prefers the method of Walton, whereas in bilateral cases, he believes the Taylor method is probably safer

Technic (Walton) —The patient is placed on the table with the head extending over the upper end of the table and being supported by the operator's hands. Under moderate traction and hyperextension, the deformity is increased by rotation of the head away from the lesion. (If the unilateral dislocation is complete the head is usually held in the position which simulates a contracture of the sternocleidomastoid muscle on the affected side if the lesion is incomplete the head is rotated to the opposite side and the neck is also bent away from the lesion) In the second maneuver the neck is bent or flexed laterally away from the dislocated side, while the increased deformity attained in the first maneuver is maintained. In the third maneuver the chin is returned to the midline and the cervical spine hyperextended.

Technic (Taylor) —With the patient on the table in a supine position and the head over the end of the table a chin and occiput sling is placed on the patient's head and the ends are passed around the operator's hips. Traction is slowly exerted through this sling, while the assistant exerts counter traction on the shoulder After the articular facets are disengaged, the spine is gently hyperextended.

Reduction of Dislocation by Skeletal Traction

Following the application of skeletal tongs to the skull (p 455) reduction may be undertaken immediately under intratracheal anesthesia or the patient may be returned to bed and reduction accomplished gradually over a period of 24 to 48 hours without the benefit of anesthesia Gallie advocates the first method

With the patient on a fracture table a special support is placed beneath the head and 20 to 30 pounds of traction is applied for 10 to 15 minutes. A roentgenogram is then made and, if correction is satisfactory traction is continued while the patient's spine is immobilized in a jacket cast from the chin and occiput to the pelvis. If the patient is observed soon after injury gentle manual force may be employed in addition to the traction

By the slower method, the patient is placed on a firm bed in a horizontal position, and 15 to 18 pounds of traction are applied to the skull tong for a

period of twenty four hours. Roentgenograms are then made to determine the status of the articular processes. If necessary, additional weight is added and the process is continued for another twenty four hours If the lateral view roentgenograms demonstrate lengthening of the more proximal articular facet to a point level with the superior border of the distal facet the head may be gradually hyperextended and the skeletal traction commensurately decreased If reduction is complete, a plaster jacket is applied the head being maintained in hyperextension.

Open Reduction of Dislocation

Frequently, the closed methods described above fail to accomplish reduction. Disengagement of the articular processes progresses until reduction is almost possible the addition of further weight, however does not materially improve the situation. In one case, we applied as much as 45 pounds of skeletal traction with the patient under general anesthesia. This, together with general manipulative measures was unsuccessful in disengaging the locked articular facets. After failure of the closed method, one s only recourse is open reduction.

In preparing the cervical spine and the base of the occiput for surgery the patient should be turned on his side and the surgeon should maintain the head, chin, and cervical spine in proper alignment Careless handling of the head and neck during preparation may produce a most undesirable neurologic complication. The operation should be carried out under local anesthesia.

Technic.—The patient is placed in a prone position, the head being supported in a well padded horse-shoe-shaped head rest. Assuming the lesion is a dislocation of the fifth or the sixth cervical vertebra the area is exposed through a longitudinal midline incision three inches in length (Fig 337) Usually the proper level may be easily determined in that the fifth cervical vertebra is the last bifid spinous process. This anatomy however is not constant nor is the spinous process of the seventh cervical vertebra necessarily the most prominent The first dorsal may be more prominent The only infallible method of determining the location consists of the insertion of a needle or pin in an exposed spinous process, followed by a lateral view roentgenogram After exposing the dislocated articular processes, the anesthetist gently flexes the neck by lowering the headstand until the head and cervical spine are in a horizontal position With the head slightly bent to the opposite side, a curved periosteal elevator is carefully hooked under the proximal articular processes while traction is constantly exerted on the head, the processes are levered into normal position. The head is then returned to a slightly hyperextended position. If reduction cannot be accomplished by this manoeuver facetectomy of the distal process is necessary If either of the articular processes do not appear well developed or facetectomy has been necessary or if the reduction appears to be unstable, the above procedure should be augmented by a Rogers type of wiring of the spinous processes of the fifth and sixth cervical spinous processes This, in turn, is supplemented by a bone graft which extends across the laminae of the involved vertebrae. Grafts from the ilium are most suitable

After Treatment.—Cervical spine traction is continued until the wound is healed, the slightly hyperextended position of the neck being maintained. Thereafter a jacket cast is applied from the chin and occiput to the pelvis



Fig. 336.—Dislocation of fifth on sixth cervical vertebra. Neurologic symptoms were temporary. Two and one-half years after open reduction and Rogers' wiring and fusion, there is a solid bony bridge from the fourth through the sixth spinous processes. The bodies of the fifth and sixth cervical vertebrae subsequently fused.

Walking in the cast is not allowed for a minimum period of eight weeks post operatively At twelve to sixteen weeks following operation a cervical spine brace is applied and worn for at least three months.

FRACTURE-DISLOCATION OF CERVICAL SPINE

As a rule, fracture-dislocations are even more serious than uncomplicated dislocations. In early cases, alignment and position may usually be restored by skeletal traction maintenance of this position is a far more difficult problem.

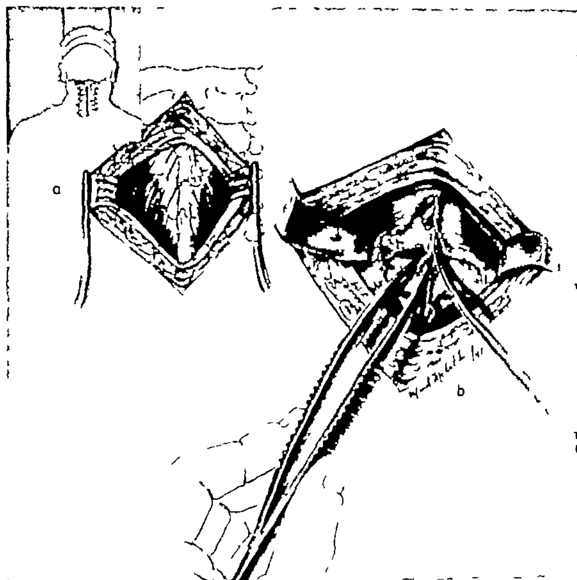


Fig. 337 —Rogers technic of open reduction of fracture-dislocation of cervical spine. Subperiosteal approach, exposing posterior aspect of cervical vertebrae, spinous process of dislocated vertebra having first been identified. (From Rogers, W A. J Bone & Joint Surg 24 245 1942.)

Many fractures of the pedicles or articular processes do not heal well As soon as the patient assumes an upright position, the deformity recurs slowly over a period of weeks or months, as the fibrous tissue stretches. Even if cord symptoms do not develop from this progressive deformity nerve root symptoms and muscle spasm with limited motion are materially incapacitating Gallie has been so

Fig. 338.—Same as Fig. 33. After reduction, fixation secured by wire loop. Hole is drilled on each side of base of spinous process and completed by Volsellum forceps and a small hook. For firm fixation, both ends of wire are passed through hole in opposite direction to form loop around spinous process. Procedure repeated in reverse through distal spinous process. (From Rogers W. A. J Bone & Joint Surg 24: 245, 1942.)

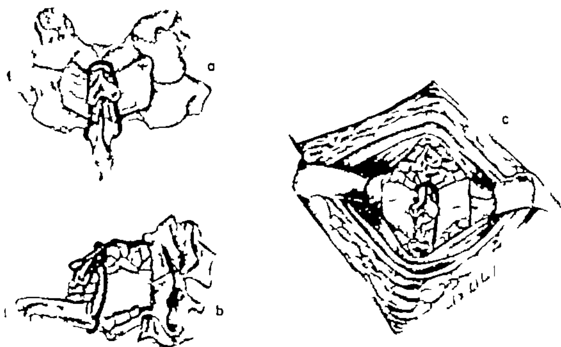


Fig. 339.—Same as Fig. 337. Wire-loop fixation supplemented by fusion with chip or iliac grafts. Note manner of applying and fixing bone graft. (From Rogers, W. Bone & Joint Surg. 24: 245, 1942.)

impressed with this tendency to recurrence, he now seriously considers the possibility of operation in every case of fracture-dislocation The trend at this clinic follows a similar line

Rogers observes that there are three cardinal points in the treatment of *fracture-dislocations of the cervical spine* namely the cord must be protected at all times, reductions must be complete or pain may ensue, and fixation must be adequate or recurrence will follow Rogers has found that closed manipulative procedures for reduction of fracture-dislocations of the spine are dangerous that incomplete closed reduction *is likely to be followed by recurrence of pain* deformity or cord injury By open operation, reduction may be accomplished under direct vision with minimal danger In the presence of fragmentation of the neural arch skeletal traction is a necessary part of the procedure Even if reduction is not accomplished by skeletal traction alone this measure is usually necessary to overcome muscle spasm to align the fragments, and to protect the cord roots during open reduction. Exceptions to the following treatment consist of bursting fractures of the atlas (Jefferson s) and the extension fracture-dislocations wherein one must rely chiefly upon skeletal traction

Local anesthesia is decidedly preferable to other forms. The patient is placed upon the operating table in the prone position with the head supported by a cerebellar head rest. In doubtful cases, skeletal traction is maintained during the operation.

Technic of Open Reduction and Fusion (Rogers).—An incision is made in the midline from the prominent spinous process of the seventh cervical vertebra to the easily palpated second cervical spinous process If the first, second, or third vertebra is involved, the incision is extended toward the occiput. The *spinous processes are identified in preparation for subperiosteal* exposure of the posterior aspect of the vertebra above and below the involved vertebra If one is in doubt as to the location of the involved vertebra a needle or pin may be inserted in the spinous process and a lateral view roentgenogram made The spinous processes lamina and posterior articulations are exposed by subperiosteal dissection if the neural arch has been fractured, exposure must be carefully carried out to prevent cord damage The spinous process is steadied by forceps during the subperiosteal stripping Reduction is then accomplished by light and gentle traction with forceps. If articular processes are dislocated, *these may be manipulated into position by the procedure described on page* 457 If reduction has been effected preoperatively roentgenograms should be made in the operating room for identification of the involved vertebra otherwise the wrong vertebrae may be fused.

Internal fixation of the fracture should be accomplished as follows usually two and sometimes three vertebrae are included in the internal fixation and fusion. If dislocated, the involved vertebra is fixed to the one below In cases of fracture the fractured vertebra is fixed to the one above, provided there is continuity between the body and spinous process of each. If continuity of bone is lacking in either the next intact arch on the same end is substituted. In some cases, the vertebrae above and below are included in the fusion

A small hole is drilled in the outer cortex of the base of the spinous process on each side. By means of a Volsellum forceps, the holes are completed to the base of the spinous process, and are then enlarged with a small hook. A wire is looped through these holes in the manner illustrated in Fig 339 The wire is passed around the superior border of the upper process, and the ends are inserted

through the hole in the process in opposite directions. The ends of the wire are then passed distally and parallel along the spinous processes to the last spinous process to be fused thence through the hole in this spinous process in opposite directions, and looped around the distal border or inferior border of this process. Before the wire is tightened a pair of periosteal or iliac grafts is laid transversely bridging each interspace. The edges of these grafts are forced beneath the parallel borders of the wire fixation to insure maintenance of the position. Multiple pieces of cancellous bone are then packed wherever possible to reinforce the main grafts.

After Treatment.—Skeletal traction is reduced to about five pounds and is continued during the period of bed rest. Ordinarily if the cord has not been damaged the patient should remain in bed three to five weeks. After the patient is allowed up internal fixation should be augmented by the use of a neck brace. This prevents any undue motion of the neck which might break the wires or interrupt the process of fusion. The brace is worn until fusion is complete which usually is from four to six months.

DISLOCATION OF THE FIRST CERVICAL VERTEBRA (ATLAS)

Dislocations of the first cervical vertebra are generally associated with a fracture of the odontoid process. Willard and Nicholson report a series of six dislocations of the first cervical vertebra, one posterior the others anterior. Three of these were traumatic in origin while the others were spontaneous dislocations, incident to infections of the cervical region. All were reduced spontaneously by the weight of the head following hyperextension. In one case, an anterior dislocation recurred six months after reduction. Conservative treatment was repeated, with the same result. One year after the dislocation, an open reduction was carried out. Traction was applied to the posterior arch of the first cervical vertebra and reduction was accomplished without difficulty. The arches were bound together with a strip of fascia lata, in a manner similar to that described by Mixter and Osgood (Fig 340). Following this procedure the dislocation again recurred. At the second operation, the fascial strip was found to have pulled free from its silk suture. Two wire sutures were then passed around the posterior arches of the first and second cervical vertebrae and the vertebrae fused by a modified Hibbs procedure.

In two cases of dislocation of the atlas on the axis, with fracture of the base of the odontoid process, Bonnet attempted reduction by suspension and the application of a plaster cast. Because of the possibility of sudden death from slipping of the bones, and injury to the cord and medulla, he employed an Albee graft to fix the occiput to the spine. This author states that the operation should not be performed immediately after the accident instead, fixation in plaster should be continued for two to three months to permit fibrous attachment of the fragments, thereby minimizing the possibility of displacement of the bones during the operation. In the cases reported by Cone and Turner fusion was performed early.

The majority of cases reported in the literature which were treated by open operative methods, were old cases wherein the deformity recurred in association with neurologic symptoms. This is certainly understandable in view of the magnitude of operative procedures in this region the exposure is rather difficult and hemorrhagic. Edema of the medulla or pressure upon the cord from subsequent hemorrhage may terminate the procedure fatally. If a progressive

increase in deformity and neurologic symptoms suggests an impending quadriplegia, or even death, correction of the deformity followed by *fusion of the* occiput to the cervical spine is justified. In one case wherein reduction could not be accomplished Boyd and Murphey a neurosurgeon, enlarged the foramen magnum and performed a laminectomy on the first cervical vertebra before the medulla was relieved of bony pressure The occiput was then fused to the cervical spine. Rogers reports a similar case In a fresh dislocation Cone and Turner decompressed the cord by a laminectomy of the first cervical vertebra. They called attention to an almost identical case which was reported by Kahn and Yglesias.

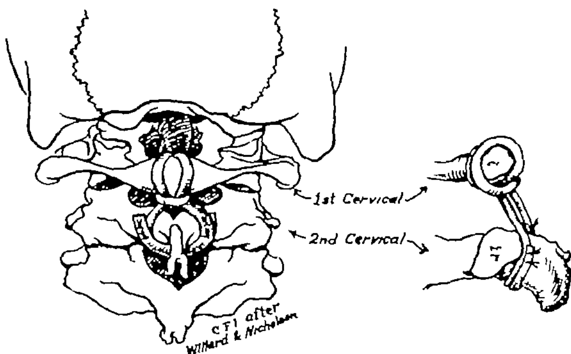


Fig 340—Mixter and Osgood procedure for stabilizing first cervical vertebra with fascial loop. A wire loop utilized in this manner supplemented by fusion, would be a more definite and *permanent means of fixation.* (*From* Willard, D. P., and Nicholson, J T: Ann. Surg. 113 464, 1941.)

As is usual with regard to relatively rare conditions, there is a lack of unanimity of opinion as to the proper treatment for dislocations of the first cervical vertebra. For a rather complete review of the literature, the reader *may refer to the bibliography recorded by Rogers.* The *technic to* be described contains features of the procedures utilized by Cone and Turner Rogers, and Willard and Nicholson. Because of the danger of a fatal termination from edema of the medulla or pressure upon the cord incident to hemorrhage, the procedure is inadvisable for fresh fracture-dislocations.

Technic of Open Reduction and Fusion.—The base of the *occiput* and the spinous processes of the second third, fourth and fifth cervical vertebrae are approached by a longitudinal incision, and the entire field is exposed subperiosteally If reduction has not been previously effected, manipulative procedures and traction on the first cervical vertebra are carried out to accomplish reduction if possible. If a laminectomy is necessary for relief of pressure on the cord, the graft must extend from the occiput to the third cervical vertebra With a Hudson burr openings are made in the occipital bone on each side of the midline approximately one *inch above the posterior arch of* the foramen

magnum. Through these openings, the dura is separated from the skull and protected while the holes are being drilled. Holes are drilled in the pedicles of the first cervical and the spinous processes of the second, third and fourth cervical vertebrae. Short lengths of wire are next passed through these holes. Two iliac grafts are now laid parallel on the laminae extending from the occiput to the third cervical vertebra, and are fastened in place by stainless steel wire loops. If laminectomy of the second cervical vertebra is not required, the first cervical vertebra is bound to the second cervical vertebra with a loop of stainless steel wire to insure stabilization, as described by Mixter and Osgood (Fig. 340). Parallel iliac grafts are then laid from the lamina of the first cervical vertebra to the third cervical vertebra.

After Treatment.—(See p. 463.)



Fig. 341.—Patient gradually developed severe neurologic symptoms from progressive displacement of first on second cervical vertebra. *Complete muscle power regained after enlargement of foramen magnum, laminectomy of first cervical vertebra, and fusion of occiput to cervical spine.*

STERNUM

Fractures of the sternum generally occur at the junction of the manubrium and body, the former being displaced anteriorly. *Even though the fracture* cannot be reduced manually and a definite deformity can be palpated, open reduction is seldom indicated. The appearance of the bony prominence constitutes the chief reason for operation; *union of the fracture in malposition* has no serious consequence.

CLAVICLE

Many fractures of the clavicle cannot be perfectly reduced by conservative measures or after reduction, cannot be maintained in perfect anatomic alignment, nevertheless, the cosmetic and functional results usually are satisfactory Nonunion is rare Even in young women or girls who are particularly anxious that there be no apparent deformity the fracture should usually be treated by rest in bed with the shoulder girdle hyperextended, with or without traction

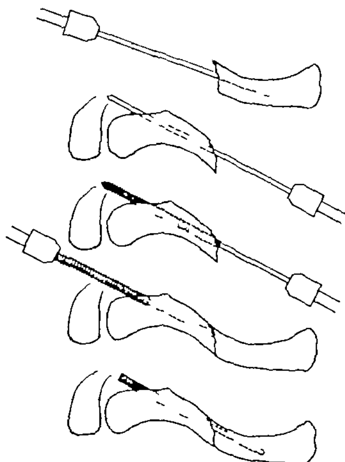


Fig. 342.—Intramedullary fixation of clavicle (D. McKeever) Intramedullary pin must be of heavy construction and stiffly tempered to withstand unsupported weight of upper extremity without bending or breaking. Threaded portion prevents pin from wandering.

Intramedullary fixation is adaptable to fractures of the clavicle. The pin must be of rather heavy construction stiffly tempered to withstand the unsupported weight of the upper extremity without bending or breaking and threaded through one half of its length this latter feature prevents the wire from wandering This method of fixation is preferable to more rigid forms of fixation such as plates

Technic (D McKeever)—A linear incision about one inch in length for transverse fractures, and as long as necessary for comminuted fractures, is made over the site of the fracture Dissection is carried down to the clavicle but the periosteum is not stripped A Steinman pin one-eighth inch in diameter is passed into the medullary canal of the proximal fragment, a distance of one and one-half to three inches, then distally in the medullary canal of the lateral frag

ment to emerge near the coracoid tuberosity of the clavicle. The skin is lightly retracted to one side a small stab wound is made and the pin is permitted to emerge through the wound This pin is then removed A one-eighth inch Steinman pin which is threaded throughout half its length is then selected The unthreaded end is cut off so that the remaining part is approximately one-half inch shorter than the depth of the hole drilled in the proximal fragment of the clavicle this end is then placed in the chuck of the hand drill and passed in a retrograde fashion into the lateral fragment of the clavicle. When it emerges through the skin the drill is reversed withdrawing the pin until the tip of the unthreaded end is at the fracture site The fracture is reduced and the pin is drilled into the proximal fragment until the beginning of the threaded portion reaches the fracture line The threaded portion must not cross the fracture line as this might produce distraction Final roentgenograms verify position The redundant portion of the pin is then cut off beneath the skin

After Treatment.—After the wound heals, the patient is ambulatory with the arm supported by a sling for one to two weeks Callus and union should be adequate in eight to twelve weeks Thereafter the wire is removed

FRACTURES ABOUT THE SHOULDER

Fracture of the Glenoid and Neck of the Scapula

Open reduction and internal fixation of fractures of the glenoid or neck of the scapula are not only difficult but the reduction is usually disappointing the same is true for skeletal traction or conservative measures. Fortunately despite medial displacement the end results are usually satisfactory If the acromion should present an obstacle to abduction an acromioplasty will provide relief

Technic.—The posterior aspect of the shoulder joint and the glenoid are exposed by a posterior approach (p 159) If exposure is limited the tendon of the infraspinatus muscle may be incised by a U shaped incision and turned back a short distance taking care not to injure the suprascapular nerve and the accompanying vessels. After exposure of the fracture the lateral fragment is grasped with forceps and with manipulation of the shoulder aligned with the main segment of the scapula. Internal fixation to meet the individual demands may consist of screws, wires or an intraosseous pin passed through the head of the humerus, across the joint into the scapula Fixation is difficult because of the limited exposure

After Treatment.—An abduction traction humerus splint is applied and worn for a period of three weeks Thereafter physical therapy is instituted the brace being worn between exercise periods for an additional three weeks.

Fracture Epiphyseal Separation, or Fracture-Dislocation of the Head of the Humerus

Fractures of the surgical or anatomic neck, or separation of the upper humeral epiphysis seldom require open reduction manipulation or traction is usually adequate unless the head is severely rotated or soft tissue interposes between the fragments, preventing proper position A mild degree of displacement, angulation or rotation is of no consequence union takes place rapidly

and function is satisfactory If an operation seems necessary reduction usually is not difficult. Fixation is secured by wire loops, screws, or by pins inserted from above downward If possible the epiphyses in children should not be violated. Usually a small triangular segment of the upper humeral metaphysis attached to the proximal fragment affords a ready means of fixing the epiphysis to the shaft

An isolated avulsion of the greater tuberosity is most commonly observed in connection with anterior dislocation of the shoulder These also may be treated conservatively unless the bony fragment retracts under the acromion. In this case, prompt replacement and fixation by sutures or wire loops is indicated to re-establish function in the short shoulder muscles. Exposure is accomplished through the posterior limb of a Cubbins approach (p 155) or a transacromial approach (p 157) (See also Supraspinatus Syndrome.)

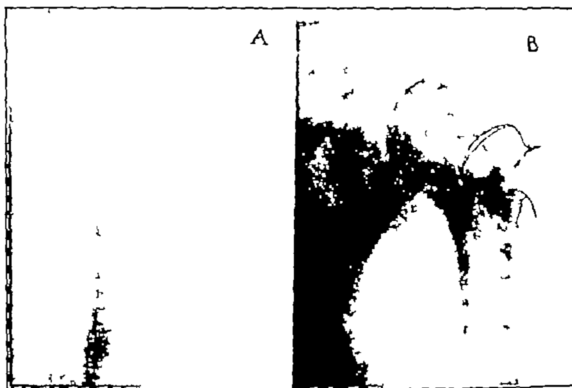


Fig. 342.—*A* Fracture through surgical neck of humerus, with dislocation of head and fracture of greater tubercle. *B* After open reduction and internal fixation with wire loops.

Fractures of the surgical or anatomic neck of the humerus with dislocation of the head usually require surgery If observed early conservative methods may occasionally succeed. Repeated, forceful attempts at closed reduction are unwarranted. Rather open reduction with re-establishment of anatomy to as near normal as possible is proper therapy While there may be limitation of motion and some pain the result is satisfactory if comminution is not too extreme. Only the technic for fracture-dislocation without comminution will be described in detail In the presence of severe comminution of the head of the humerus and the tuberosities, an assembly of the fragments may be relatively impossible. Here, the Jones reconstruction procedure (p 472) is applicable, particularly in middle-aged or elderly individuals.

Technic.—The shoulder is exposed by a Cubbins incision (p 165) The deltoid is reflected backward and laterally to provide adequate exposure. Usually, the head of the bone is entirely extra articular and without soft tissue attachments. The rent in the capsule is enlarged, the head replaced in the joint and apposed to the shaft A small, proximal fragment may be fixed by a technic similar to Nicola's operation for recurrent dislocation the long head of the biceps is divided at the bicipital groove and the proximal end drawn through a hole drilled in the distal fragment and the head of the humerus.

If the proximal fragment is large fixation may be secured with wire loops or screws, or a pin may be inserted vertically through the lateral border of the head into the shaft Avulsion fractures of the tuberosities are fixed to the head by loops of stainless steel wire Removal of the lateral two-thirds of the acromion process permits a better range of motion and a less prolonged convalescence

After Treatment.—The Campbell traction humerus splint (p 65) is applied with only sufficient traction to maintain fixation Active and passive motion and physical therapy are begun at the end of three weeks.

The end results of this procedure depend upon the rapidity of revascularization of the loose fragment. The head of the bone is in reality a free graft as the upper fragment is completely detached and a new blood supply must be established for regeneration and union As the normal contour is rarely maintained, in adults some incongruity of the head of the bone with a commensurate loss of function may be anticipated In young individuals perfect function may be restored

Comminuted Fracture of the Head of the Humerus

Comminuted Fracture-Dislocation of the Shoulder

Heretofore, the surgical treatment of these traumatic lesions has been more or less ignored in that no satisfactory method has been available Many of these injuries take place in elderly individuals thus any extensive operation on the shoulder is likely to be followed by pain and considerable limitation of motion. The head of the humerus being in several pieces, and the tuberosities usually being avulsed, fixation of all pieces and restoration of any semblance of normal anatomy is practically impossible Mere excision of the head of the humerus and its comminuted fragments has long been recognized as entirely inadequate, since voluntary muscle control of the shoulder postoperatively is essentially nil or the function of the shoulder is extremely impaired because of stiffness.

Laurence Jones has devised a tendoplastic reconstruction for any traumatic entity wherein the head of the humerus must be removed this procedure solves many of the difficulties attendant upon reconstruction of a fairly serviceable extremity We have employed the method in a relatively small series of cases, with gratifying results. Jones operation is based upon sound anatomic and physiologic principles (1) that movement of the shoulder demands fixation of both the glenoid and the head of the humerus, two distinct muscle systems being involved (2) that the major function of the capsular or ' short rotator muscles is stabilization of the head of the humerus in the glenoid cavity (3) that the anterior and posterior groups of the short muscles are of approximately the same weight and muscle volume, and are symmetrically placed opposite each

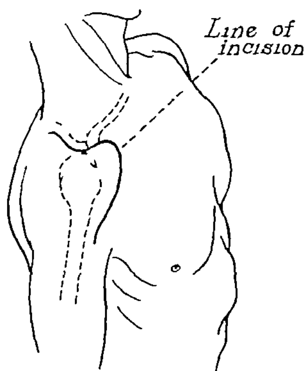


Fig. 344.—Laurence Jones' tendoplastic procedure for comminuted fractures of head of humerus, or comminuted fracture-dislocations of shoulder. Skin incision for Cubbins approach to shoulder. (From Jones, Laurence: Surg. Gynec. & Obst. 75: 433, 1942.)

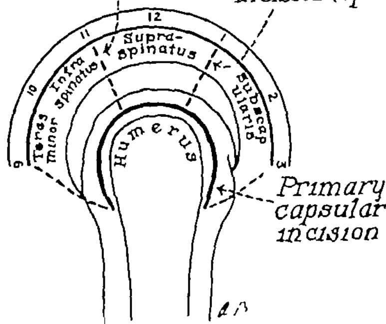


Fig. 345.—Same as Fig. 344. Diagram of "horseshoe" and "shoulder clock" aids in proper localization of capsular flaps. See also Figs. 365, 366, 367. (From Jones, Laurence: Surg. Gynec. & Obst. 75: 433, 1942.)

other, they pull not only against their bony insertion but against each other through the supraspinatus tendon (Ch XX) In the technic described below this relationship is re-established and gives the muscles the added purchase of a lower insertion

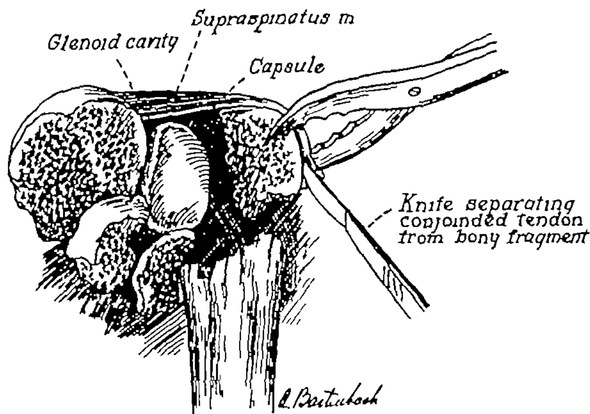


Fig. 346.—Same as Fig 344. Head of humerus and comminuted fragments removed from joint. Bony fragments adherent to conjoined tendon separated by sharp dissection. (From Jones, Laurence Surg., Gynec. & Obst. 75: 433 1942.)

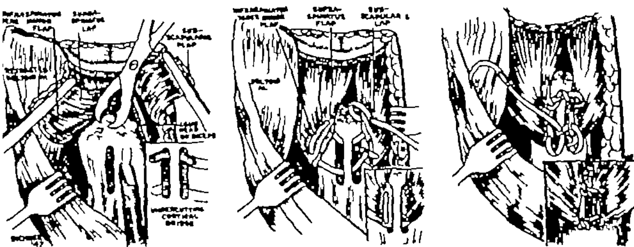


Fig. 347.—Upper end of humeral shaft reshaped and two grooves created for reception of capsular components. Posterior flap (supraspinatus-infraspinatus-teres minor) and anterior flap (subscapularis) laced into grooves with a strip of fascia lata. (From Jones, Laurence Surg., Gynec. & Obst. 75 433 1942.)

The preoperative requirements are as follows (1) A properly fitting abduction humerus splint which will maintain the shoulder in neutral rotation and at a position of 135 degrees abduction must be available (2) The patient

must be placed on his side with the injured shoulder uppermost adequate posterior exposure is impossible with the patient in the supine or a semirotated position. (3) An assistant must be available to hold the hand and semiflexed forearm, manipulate the extremity through a wide range of rotary movements, and, finally, to maintain the shoulder in a fixed position of neutral rotation and 135 degrees abduction during the implantation and fixation of the flap This position must be maintained continuously until the arm is immobilized on the abduction humerus splint.

Tendoplastic Repair (Laurence Jones)—The shoulder is exposed by a complete Cubbins incision (p 155) A fringe of muscle and fascia is left attached to the clavicle, acromion and spinous process of the scapula to facilitate final closure and resuture of the deltoid muscle The anterior two-thirds of the deltoid is separated bluntly from the underlying structures, and retracted laterally and downward A horseshoe shaped incision is made from before backward along the margin of the bicipital groove the lesser tuberosity and the margin of the greater tuberosity, detaching the capsule and conjoined tendons from the humerus. If this mobilization has been accomplished wholly or in part by fragmentation of the tuberosity and the head each capsular attachment is removed from the comminuted bony fragments. From a lateral view of a right shoulder the short shoulder tendons are attached to the humerus clockwise as follows the subscapularis tendon is situated between one and three o clock, the supraspinatus tendon is between one and eleven o clock, and the conjoined tendon of the infraspinatus and teres minor is situated between nine and eleven o clock. An incision which begins at the margin of the greater tuberosity at one o clock, and extends toward the coracoid process affords an excellent exposure of the shoulder joint and mobilization of the tendons. The subscapularis flap is completely mobilized by detachment from the lesser tuberosity and, below by sharp dissection along the bicipital groove If fractured, the lesser tuberosity is dissected away from the subscapularis flap Similarly a superior and posterior flap consisting of the conjoined tendons of the supraspinatus, infraspinatus, and teres minus is created. Mobilization of all flaps is completed by transverse incisions at the base of the horseshoe. Thereafter all comminuted fragments of the head of the humerus are removed, together with any segments of the tuberosities The upper end of the humerus is rounded off with bone-biting forceps. Two inches below the rounded end of the bone, two longitudinal slots of appropriate size to receive the two flaps are formed in the shaft of the humerus. The medullary under-cut converts these into a bony tunnel, as illustrated. A strip of fascia lata from the lateral surface of the thigh is affixed to a Gallie fascia needle and utilized to suture the anterior (subscapularis) flap and the posterior (infraspinatus teres minor supraspinatus) flap in their respective slots and to each other by a reinforcing outside buttress suture All flaps should be taut with the arm abducted to 135 degrees. Finally, the deltoid muscle is resutured to the acromioclavicular fringe

After Treatment.—The upper extremity which has been maintained continuously in neutral rotation and at 135 degrees abduction is immobilized on an abduction humerus splint. Physical therapy and abductive exercises, beginning with shrugging of the shoulders, are instituted as soon as the sutures are

removed. With the return of muscle power, complete abduction with the arm still supported on the splint is carried out, followed finally by rotary exercises. The splint is usually removed four weeks postoperatively, but is worn at night for an additional two to four weeks.

The end result of this reconstruction procedure is not a normal shoulder, any more than a Whitman reconstruction of the hip produces a normal member. It is, however, the best course in any situation wherein the head of the humerus must be removed, and provides a stable shoulder with relatively excellent muscular function and a most satisfactory range of motion.

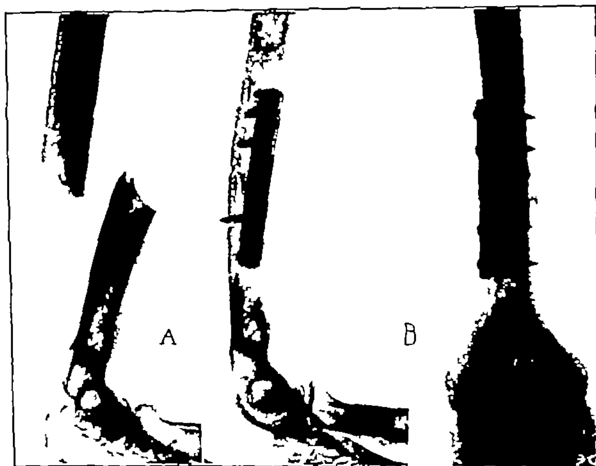


Fig. 248.—A Short oblique fracture of shaft of humerus. B Fixation with Vitallium plate and four screws.

SHAFT OF THE HUMERUS

Since the introduction of hanging casts we seldom resort to open reduction of fractures of the shaft of the humerus. This treatment has been eminently more satisfactory and easier for us and for the patient than the older closed methods or the newer, surgical procedures.

Briefly open reduction and internal fixation are indicated when the hanging cast, and occasionally, other closed methods, are either not applicable or less efficient, as, for example, (1) associated injuries which necessitate bed rest, (2) fracture of the lower metaphyseal region of the humerus, (3) segmental, or third fragment fractures, and (4) associated injuries of the elbow which require early mobilization.



Fig. 349.—Comminuted segmental fracture of shaft, we believe, is essentially only indication for use of intramedullary pin in humerus.

The ordinary methods of fixation described earlier in this chapter (p 374) are applicable to the humerus, namely, transfixion screws for long oblique butterfly, or torsional fractures, and plates and screws for short oblique, or transverse fractures. Intramedullary pins may also be used for the latter group, but are particularly suitable for comminuted or segmental third fragment fractures, or for associated injuries which require early mobilization of the elbow wrist and fingers. The approaches to the shaft of the humerus are described in Chapter IX

Intramedullary Fixation of Fractures of the Humerus—Küntscher nails must be available in lengths from 20 to 28 cm., and in diameters of 5, 6, and 7 mm A round rod a little larger than the ordinary Smith Petersen guide pin will also serve quite satisfactorily

The humerus may be pinned from either end. If pinned from the distal end, the nail must be sufficiently long to engage the cancellous portion of the head of the humerus The wide intramedullary portion of the upper third of the shaft does not give the pin sufficient stability and purchase The distal end of the pin must be relatively flush with the bone otherwise the triceps tendon may be irritated

The approach from the proximal end of the bone has these advantages the pin is always engaged in the cancellous portion of the head the length of the pin does not have to be as exact if the pin traverses the fracture distally by four inches, fixation ordinarily will be stable

Technic for Distal End of the Humerus—A two-inch incision is made over the posterior surface of the lower end of the humerus, approximately two inches above the olecranon fossa. The bone is exposed through a longitudinal incision in the triceps tendon With a drill and chisel, a slot is created in the posterior cortex of the humerus, of sufficient size to allow introduction of the pin into the intramedullary portion of the lower fragment as far as the fracture site The position of the pin is then changed so the humerus may be exposed on its anterior surface. After exposure of the fracture site and reduction of the ends of the fragments, the nail is introduced into the proximal fragment, and thence up to the head of the humerus. Roentgenograms should be made before driving the nail home that one may be certain the nail is of proper length. The end of the nail should be approximately one half inch from the articular surface of the shoulder joint

Technic for Proximal End of the Humerus.—The patient is placed in a prone position with a large sandbag beneath the shoulder With the arm adducted and in internal rotation a small longitudinal incision is made over the lateral aspect of the acromion The deltoid muscle is split and detached from the acromion over a short area sufficient to expose the greater tubercle Dissection too far distal endangers the axillary nerve A hole is then drilled through the humerus at a point directly behind the greater tubercle and the pin is introduced through this hole across the fracture as described above The distal end of the pin should traverse the fracture site by at least four inches.

After Treatment.—The arm is immobilized on an abduction humerus splint until the soft tissue wound is healed Thereafter only a sling is necessary and active exercises may be begun immediately

LOWER EXTREMITY OF THE HUMERUS

Operations will be described for reduction of the following fractures (1) T fractures (2) side-swipe fractures, (3) fractures of the articular surface (4) fractures of the humeral condyles in children, i e. (a) supracondylar fractures, (b) fractures of the medial condyle, (c) separation of the medial epicondyle of the humerus, (d) fractures of the lateral condyle, (5) fractures of the humeral condyles in adults

T Fractures

In the adult, the most common type of fracture involving the lower end of the humerus is the T fracture, in which the fracture line starts in the groove on the articular surface of the trochlea and extends upward between the condyles for varying distances, then transversely across the shaft, separating the condyles from each other and from the shaft itself The muscle tension exerted on the outer edges of the condylar fragments pulls them distally tilting the central portion of the articular surface proximally and resulting in a V shaped deformity These fractures are caused by considerable violence and are frequently associated with compound wounds. Closed reduction or skeletal traction usually is followed by tilting and rotation of the fragments resulting in narrowing of the humeral articular surface from the V-shaped deformity As the olecranon cannot fit properly into this narrowed surface full extension of the joint is inhibited If the fracture is not compound, open reduction, with some type of internal fixation is usually preferable to conservative methods.

Van Gorder has stressed the fact that restoration of the articular surface of the humerus must be relatively anatomic if the end result is to be satisfactory The secret of success in proper apposition of the fragments and the insertion of metal fixation is an adequate exposure. Van Gorder points out the advantages of the Campbell posterior approach to the elbow as follows (1) it is preferable to other forms of approach as the fracture is adequately exposed (2) because of the wide exposure, more freedom in the selection of the type of internal fixation is allowed (3) there are no large blood vessels or nerves in the area of the incision the ulnar nerve being previously identified and retracted medially (4) it is the only approach to the elbow which affords a clear view of all of the involved articular surfaces of the joint line.

Another proposal by Van Gorder facilitates the operation. The patient is placed in a prone position on the table with the arm resting over the edge of an armboard, the elbow being at a right angle. The preoperative roentgenograms of supracondylar T fractures of the humerus should be studied carefully before the operation and the exact type of fixation should be selected so the plate may be bent to conform to the general contour of the area to which it is to be applied. A proper assortment of screws wires, Knowles pins, and *butterfly* plates should be available.

Technic.—The elbow joint is exposed by the Campbell posterior approach (p 162) The condylar fragments are manipulated into satisfactory alignment and the contour of the humeral articulation is restored to as near normal anatomy

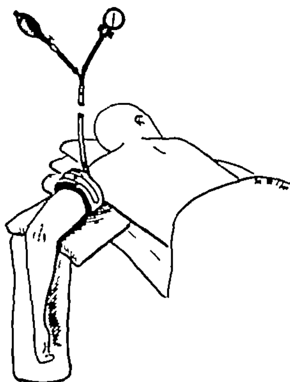


Fig. 350.—Prone position with elbow flexed ov r arm board facilitates open reduction of fractures involving elbow joint and lower metaphysial region of humerus. (From Van Gorder G W J Bone & Joint Surg. 22: 2 8 1940.)

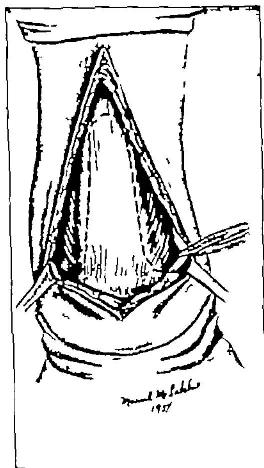


Fig 351

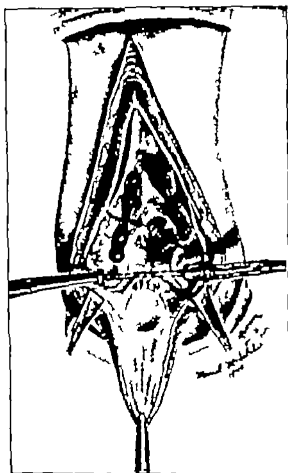


Fig. 352.

Fig. 351.—Campbell posterio approach to elbow joint provides wide exposure for open reduction of T fractures on condyles. (From Van Gorder G. W : J Bone & Joint Surg 22: 278 1940.)

Fig. 352.—Open reduction and internal fixation of T fracture of condyles of humerus. (From Van Gord G W J Bone & Joint Surg. 22: 278 1940.)

as possible Loose fragments of the articular surface which cannot be replaced must be removed, as the small particles of bone probably will not unite, but will become loose bodies and give rise to traumatic arthritis. In this event, perfect approximation and restoration of the articular contour is of course impossible.



Fig. 353 —T fracture of condyles of humerus fixed by three transfixion screws.

The alignment is maintained by means of forceps, while a Knowles pin or screw is inserted transversely from one fragment into the other This converts the *T* fracture into a supracondylar fracture Fixation of the supracondylar fracture may then be completed by the application of a plate to the posterior aspect of the humerus or by the insertion of two long screws in an X fashion across the fracture site If a Y plate is used the order of procedures is as follows one limb of the Y is fixed to a condylar fragment The two condyles are next

apposed and their fixation is completed by a screw inserted through the opposite limb of the Y. The supracondylar portion of the fracture is then reduced and the longitudinal limb of the Y affixed to the metaphyseal portion of the humerus by a screw.

After Treatment.—The arm is immobilized in an abduction humerus splint. Unfortunately, the elbow cannot be mobilized at an early date on account of the transverse fracture above. Six to eight weeks may elapse before union is sufficiently solid to permit any movement. This fact usually accounts for the poor results secured; seldom if ever, is normal function restored. A range of flexion to 80 degrees and extension to 160 degrees with relatively normal rotation of the forearm is regarded as an excellent result. Fibrous ankylosis of the elbow is not infrequently encountered, and occasionally osseous ankylosis develops. Should ankylosis be present to a degree which prevents a practical range of motion, restoration of the contour by open operation will facilitate subsequent arthroplasty.

Side-Swipe Fractures

"Side-swipe" fractures are clinical entities only so far as the mode of injury is concerned; namely, an elbow which is allowed to protrude from a car window is struck by an automobile passing in the opposite direction. Here, aside from the gravity of the injury, all similarity ceases; bizarre and grotesque combinations of fractures may be produced by this type of injury. Associated soft tissue injuries vary from minor lacerations and excoriations to massive Type III compound wounds.

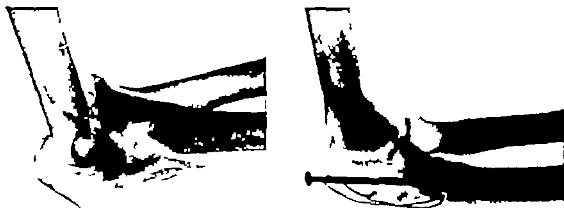


Fig. 354.—Compound comminuted fracture of olecranon with anterior dislocation and displacement of head of radius and shaft of ulna, sustained by "side-swipe" injury. Alignment of multiple fragments maintained and recurrence of dislocation prevented by intramedullary pin and circumferential wire loop.

The most common combination consists of a comminuted fracture of the olecranon at the level of the coronoid process, associated with anterior dislocation of the head of the radius and the distal fragment of the ulna. Fracture of the middle and lower third of the shaft of the humerus is usually associated.

Treatment consists of reduction of the anterior dislocation and fixation of the comminuted fracture of the olecranon by the use of an intramedullary wire. A hanging cast is applied, usually by the tenth day for the fracture of the humerus.

To this basic combination any or all of the following fractures may be added (1) *Fracture of the shaft of the ulna.* The intramedullary wire employed to fix the comminuted fracture of the olecranon also serves to immobilize the fracture of the shaft of the ulna. The wire should be inserted in a retrograde manner from the shaft fracture (p 504) however, as in this manner a minimum amount of contaminated material is carried down the intramedullary canal. (2) Comminuted fracture of the head of the radius. The Boyd approach (p 187) affords adequate exposure of the fracture of the olecranon and the comminuted fracture of the radius. Treatment of the latter consists of removal of the radius to the proximal edge of the orbicular ligament. (3) Fracture of the shaft of the radius. This fracture is immobilized by the use of an intramedullary wire (p 506) or other means. (4) T fracture of the condyle of the humerus. Fixation of this injury is secured as described above (p 476)

Every fracture cannot receive complete attention immediately following the injury *Attention is particularly directed toward the care of the compound* wound and toward the restoration of the elbow joint If necessary fractures of the shafts of the long bones may be neglected until a later date. In the presence of so many injuries in the same extremity, nonunion of one or more fractures of the shaft of the long bones may be anticipated for these, an onlay bone-graft procedure will be required. Trauma to the elbow joint is usually so severe that residual disability is certain. Results vary from a complete ankylosis to a fairly serviceable range of motion. Frequently, fibrosis or callus formation in the soft tissues and about the joints is so extensive that only a few degrees of motion remain. Even so restoration of contour of the elbow to as nearly normal as possible creates conditions favorable to future restoration of motion by an arthroplasty

In elderly people, or with comminution so extensive that assembly of the pieces is impossible, conservative treatment is in order While the roentgenographic and cosmetic appearance of the elbow may not be pleasing many patients will do fairly well.

Fractures of the Articular Surface of the Humerus

Treatment should be selected according to the degree of displacement of the fragments and the extent of damage to the articular surfaces. Surgical intervention is always warranted unless the fracture is incomplete, or there is only slight or no displacement. The most common injury is a fracture of the articular surface of the capitellum. Roentgenograms may be misleading as to the size of the fragments. Frequently a large segment of articular cartilage is sheared off with a minimal amount of cancellous bone. The fragment is thus considerably larger than the roentgenogram would lead one to believe. In this respect, the injury is somewhat comparable to tangential fractures of the patella. More extensive trauma may produce a fracture of the anterior half of the capitellum, or a fracture of the entire capitellum together with a small piece of the trochlea.

If the fragments are small (Fig 407) treatment is carried out as for a loose body Usually a lateral approach is adequate (p. 165) The loose fragment of bone is removed, the joint is thoroughly inspected for small pieces of cartilage or bone and the fractured surface of the condyle treated so as to present as smooth an articular surface as possible.

If the fragments are large replacement and internal fixation may be possible in a manner similar to that employed for fractures of the external or internal condyle (p 485)

In more extensively involved articular surfaces in adults, replacement of the fragments may be impossible Another alternative excision of the fragments, may leave such an incongruous and irregular surface as to be incompatible with function If the dimensions of the expanded lower end of the humerus are adequate to permit the construction of a new condyle, a modified arthroplasty should restore excellent function

Technic.—A posterolateral incision (p 162), beginning five inches above the elbow and terminating one inch below, is made parallel with the external border of the aponeurosis of the triceps muscle Dissection is continued through the outer edge of the aponeurosis to the humerus thence distally through the posterior capsule of the joint to just below the head of the radius With a periosteal elevator the periosteum is stripped from the lower two inches of the posterior surface of the humerus The ulnar nerve just posterior to the internal condyle is avoided by dissection close to the bone The ligamentous and muscular attachments of the external condyle are separated subperiosteally and the joint is dislocated One should be particularly careful to preserve the capsule and the periosteum intact on the anterior surface if there is excessive stripping of the soft tissues, through which a large portion of the circulation is derived, sequestration of the reconstructed articular surfaces may take place later The fracture site is then thoroughly examined and all loose particles are removed The damage to the bone and cartilage is always much more extensive than is apparent in the roentgenogram

The radius and ulna are displaced backward and rotated outward in order to permit adequate exposure of the articular surface of the humerus. With a chisel and osteotome, the lower extremity of the humerus is now made into one convex condyle the internal side being slightly longer that the carrying angle may be preserved if possible The contour is then rounded and smoothed with a file and reduction is effected The periosteum over the posterior surface of the humerus, and the posterior capsule are closed with No 0 plain catgut, and the aponeurosis of the triceps, and the deep fascia are similarly sutured

After Treatment.—The elbow is immobilized in a posterior metal right angle splint If a modified arthroplasty has been employed active and passive movements and physical therapy are instituted after ten days.

Motion ranging from 50 degrees' flexion to full extension is restored Function returns rather rapidly permitting the patient to resume his occupation after six weeks unless engaged in manual labor The interposition of fascia lata as in arthroplasty seems to be unnecessary because of the wide joint space provided by excision of the small fragments of bone and the presence of normal articular cartilage in the semilunar notch of the ulna

Fractures of the Humeral Condyles in Children

Each of the numerous fractures observed about the humeral condyles in children present so many factors that are peculiar to themselves that a detailed description of each is warranted. In the subsequent sections it is assumed that we are dealing with complete and displaced fractures incomplete fractures of

the humeral condyles without displacement may be treated by conservative measures, with uniformly perfect anatomic and functional results. A substantial number of supracondylar fractures will require open reduction and internal fixation. Condylar fractures, almost without exception, should be opened and stabilized by some form of internal fixation, otherwise, in almost every case, nonunion or malunion of the external condyle, or malunion of the internal condyle followed by a sequence of complications, will be the outcome.

Certain features of condylar fractures are common to all. The impression gained from the roentgenogram at the time of fracture may be misleading since the fragment, which consists chiefly of cartilage in the younger age group, does not appear large and the displacement, although in reality pronounced, may not seem appreciable. Attached to the internal and external condyles are the strong flexor and extensor groups of forearm muscles, respectively. After fracture, the condyles are displaced by the pull of these muscles and often turned end over end and rotated. Although free access to the fracture site is obtained at operation, difficulty may be encountered in accurately fitting the fractured surfaces together. After reduction is accomplished, the necessity for some form of internal fixation is easily demonstrated if the attached muscles are placed under slight tension, the most gentle traction will displace the fragment. A rustless steel wire nail fulfills all the requirements. In many cases, the nail must be driven through the line of epiphyseal attachments, although this is a theoretical objection, no irregularity in growth or premature ossification from this source has been observed following this procedure. Ordinarily, the wire fixation may be removed six to eight weeks after insertion.

In 1945 Boyd and Altenberg made a survey of all of the fractures about the elbow in children treated at the Campbell Clinic. They studied 713 fractures in children of twelve years of age or younger distributed according to the following table:

		NO. CASES	PERCENTAGE
Supracondylar fractures		465	65.4
Condylar fractures		180	25.3
Lateral condyle	124		
Medial epicondyle	33		
Medial condyle	23		
Fractures of the neck of the radius		34	4.7
Monteggia fractures		16	2.2
Olecranon fractures		12	1.6
T condylar fractures		6	0.8
Total		713	100.0

This study has substantiated our ideas in regard to the indications and the type of treatment for these fractures. The subsequent sections deal only with the fractures of the lower end of the humerus in children. Fractures of the neck of the radius, Monteggia fractures, olecranon fractures, and T condylar fractures are discussed elsewhere.

In all fractures about the elbow in children, the question arises as to damage to the nerves and impairment of circulation. The surgeon is spared considerable embarrassment by ascertaining the existence of injury to nerves or vessels before rather than after treatment; this is particularly true in supracondylar fractures. If the patient can fan the fingers with the metacarpophalangeal joints extended and can oppose the thumb to the little finger, the

three major nerve trunks are intact. The sensory distribution of these nerves should also be tested. Impairment of circulation is manifested by a diminution or absence of the radial pulse and the presence of swelling, cyanosis and paresthesia or anesthesia of the hand and fingers. The same examination should be repeated following treatment.

Ischemic or Volkmann's contracture is a common complication following fractures about the elbow, particularly, supracondylar fractures. This complication may be unavoidable. Observation of the circulation of the hand, however, is an essential part of the after-treatment. If open reduction and internal fixation have been employed, circulatory disturbances are less likely to arise; apparatus may be loosely applied or may be temporarily discarded if indicated, without fear of losing the reduction. Further, acutely flexed positions of the elbow are neither necessary nor desirable. To prevent tourniquet paralysis, care should be exercised in their application and use. Pneumatic tourniquets are preferable in that the exact amount of pressure is known and is distributed evenly over the upper portion of the arm; a definite time limit should be rigidly observed.

Supracondylar Fractures

In the study made by Boyd and Altenberg, supracondylar fractures represented well over one-half of the fractures of the elbow in children, being most common in those between the ages of five and eight years. In this series of 465 cases, the radial nerve was damaged in 2.4 per cent and the median nerve in 1.5 per cent. Ulnar nerve lesions were manifested in only two patients. In practically every case the damage to the nerves was of a transient nature. In only two was exposure and suture of the nerve necessary, the radial nerve being involved in both.

In the majority of cases, a satisfactory anatomic restoration may be accomplished by closed measures. If the fracture is observed relatively early, immediate manipulation and reduction are indicated. If swelling of the soft tissue precludes the Jones' position, conservative measures, such as those described by Dunlop and by Hart, may be instituted. Occasionally, all of these methods fail. This is particularly true in the presence of oblique fractures in the supracondylar region which end in a thin, pointed spicule of bone as viewed in the anteroposterior roentgenogram. Fishtail or staghorn type supracondylar fractures, and transcondylar fractures, are also maintained in position with difficulty. We have found open reduction necessary in approximately one in every ten supracondylar fractures. This is a little higher than the average series, since many of these patients were referred to us after manipulative procedures had failed elsewhere. Approximately one-half of this number were so old that a considerable amount of callus was present at the fracture site; the other half were fresh fractures which we were unable to reduce or to maintain in a satisfactory position by closed methods.

Technic.—Both the medial and lateral surfaces of the elbow are incised for an appropriate distance, beginning just distal to the elbow joint and extending proximally to the fracture site. By posterior retraction of the ulnar nerve and dissection close to the bone no important structures are injured. The lateral incision is well posterior and lateral to the radial nerve; nevertheless, the

tissues should be dissected subperiosteally. If both fragments are under direct vision, reduction and alignment are not difficult.

Internal fixation of one side alone is inadequate. On the medial side, a rustless steel wire nail is inserted through the internal condyle and drilled upward and laterally. On the lateral side the nail is inserted through the ex-

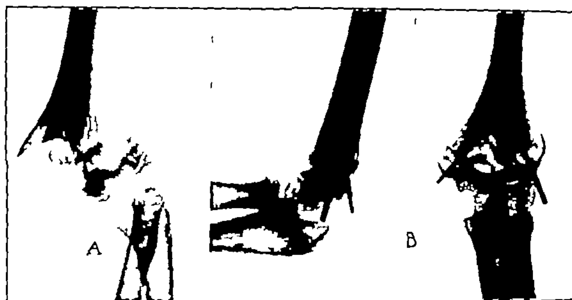


Fig. 355.—*A* Supracondylar fracture of humerus. Reduction or maintenance of reduction by conservative means frequently impossible in oblique fractures involving olecranon fossa, with extreme displacement. *B* After open reduction and fixation by two wire nails.

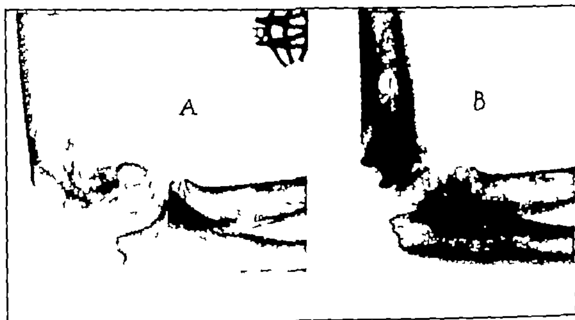


Fig. 356.—*A* Supracondylar fracture with anterior displacement of condyles. *B* Treated by open reduction and internal fixation.

ternal condyle and drilled in an upward and medial direction. Both nails should be parallel to the longitudinal axis of the humerus in the lateral view and at an angle of 35 to 45 degrees to the shaft of the humerus in the anteroposterior view. The tips of the nails should engage the opposite cortex. Roentgenograms are

made to verify the position of the fracture and the position of the wire nails. At the conclusion of the operation the excess length of the wire nail is clipped off, a sufficient amount being left to facilitate identification and removal at a later date

After Treatment.—The arm is placed in a right angle elbow splint. After two weeks active and passive motion and physical therapy are begun, while some form of support is maintained for an additional three weeks. The end results of open reduction of this fracture are uniformly excellent, with the possible exception of some slight limitation of motion in a small number of patients.

Fracture of the Medial Condyle of the Humerus

Almost invariably, fractures of the medial condyle of the humerus in children should be reduced under direct vision and maintained in position by internal fixation Anatomic position is necessary to prevent disturbances in growth Even though such a position could be achieved by manipulative measures the muscular pull by the common origin of the flexor muscles would lead to displacement If the medial condyle is in malposition the lateral condyle will usually grow faster than the medial condyle thus producing a cubitus varus deformity and perhaps eventuating in a severe traumatic arthritis. Malunion and growth disturbances are preventable by early anatomic reduction and internal fixation

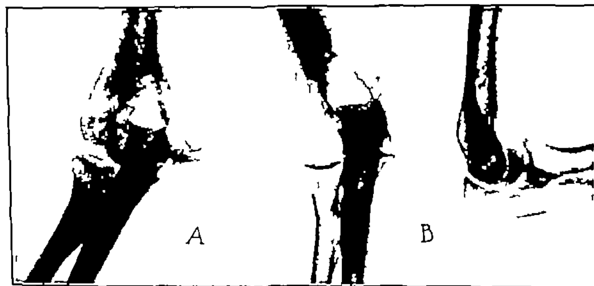


Fig. 15 —*A* Fracture of medial condyle of humerus. *B* Eleven years after open reduction and internal fixation complete range of motion.

Technic—A medial incision is begun just distal to the fractured condyle and extended proximally three inches parallel with the humerus Dissection is carried down to the bone, the ulnar nerve being isolated and retracted posteriorly The capsule of the joint usually is widely ruptured and need not be incised for exposure of the fracture site The detached condyle is carefully examined and all loose particles of bone are removed One may be surprised by the size of the fragment as frequently a large portion of the trochlea is included The fractured surfaces are brought into apposition by means of towel clips or Ochsner clamps, the soft tissue attachments of the

fragment remaining undisturbed If there are no loose fragments, the normal contour of the articular surfaces should be restored A rustless steel 1.5 mm. nail is drilled through the fragment into the humerus in an upward and outward direction. Fixation should be firm Before closure of the wound roentgenograms should be made *to insure perfect apposition.*

After Treatment.—The arm is immobilized in a right-angle elbow splint for a period of three weeks. At that time roentgenograms are again made to determine whether the position remains accurate Exercises are begun, the elbow being supported in a splint between exercise periods. After an additional two weeks, active use of the elbow may be gradually resumed

Although no ill effects may be produced by leaving the nail in situ, six weeks following operation a small portion of the incision may be reopened under local anesthesia and the nail withdrawn

Fracture or Epiphyseal Separation of the Medial Epicondyle of the Humerus

Avulsion of the internal epicondyle is in reality an epiphyseal separation caused by tension of the *flexor group of muscles* From the standpoint of treatment, the condition is comparable to fractures of the humeral condyles. To obtain union and prevent arrest of growth in the epicondyle the separated surfaces must be placed in close coaptation and so maintained until union occurs. Although excellent function has followed conservative measures in the majority of cases, delayed ulnar palsy occasionally results from adhesions about the nerve and deformity in the ulnar groove. Open reduction and fixation with a wire nail is a relatively simple procedure and has proved the most efficient form of treatment The technic is similar to that described below

Fracture or Epiphyseal Separation of the Medial Epicondyle of the Humerus With Displacement Within the Elbow Joint

Frequently the nature of this fracture is undiscovered until the joint is irreparably damaged Because of the difference in density between the cartilage of the epicondyle and the bones of the joint, the exact location of the displaced epicondyle may be difficult to determine by roentgenograms The *loose fragment is carried into the joint* with a portion of the capsule.

Technic.—A medial incision three inches in length is begun just distal to the elbow joint and carried proximally parallel with the medial surface of the humerus. When the normal location of the epicondyle is exposed only the raw surface of the condyle is seen No loose fragment is visible The ulnar nerve lies posteriorly and apparently is uninjured. Inspection reveals the medial capsule the musculotendinous origin of the flexor muscles and the epicondyle folded within the joint covering the lower portion of the coronoid fossa and the coronoid process. With a small tenaculum the epicondyle with its soft tissue attachments are extracted from within the joint the epicondyle is then approximated accurately to the fractured surface of the humerus, and the rent in the capsule sutured. Should this not effectually maintain apposition a small wire nail may be inserted.

Aitken and Childress believe that in every case the ulnar nerve *should be* transplanted anteriorly to prevent further damage by rubbing over the rough

epicondylar bed of the humerus, or by being caught in the fibrous tissue during healing of the fracture We have not found this necessary

After Treatment.—A right angle elbow splint is applied and worn for three weeks At that time, active motion of the elbow is gradually resumed Subsequently the nail may or may not be removed, as desired

This is a far more extensive lesion than simple separation or fracture of the internal epicondyle, hence, recovery is slow Results are excellent if operation is carried out at the time of fracture The outcome is less successful if treatment is delayed

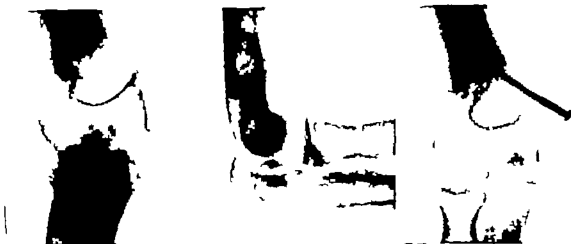


Fig. 358.—Fracture of medial epicondyle of humerus with bony fragment displaced into joint. After open reduction, fragment replaced and fixed with screw

Fracture of the Lateral Condyle of the Humerus

Fractures of the lateral condyle are far more common than those of the medial condyle or medial epicondyle The normal carrying angle of the elbow predisposes a valgus strain when forces are transmitted through the forearm to the elbow Unless perfect apposition and relationship to the fracture surfaces are secured and maintained, the loose fragment is frequently rotated through 180 degrees from its normal position The ultimate disability is even more severe than that which follows unreduced fractures of the internal condyle i.e. nonunion with impairment in growth cubitus valgus deformity and delayed ulnar palsy In the presence of even the slightest displacement early open reduction and internal fixation are necessary With delay fibrous tissues and callus develop rapidly making accurate replacement difficult. If as much as four weeks elapse between time of the fracture and open reduction, growth disturbances will be the rule rather than the exception.

Technic.—Beginning one inch distal to the elbow joint, the incision is extended proximally three inches on the external aspect of the joint. Dissection is carried down to the external condyle of the humerus By separating the structures close to the bone an adequate exposure of both the posterior and anterior surfaces of the joint may be obtained As with the internal condyle the displacement is more pronounced and the fragment usually larger than is apparent in the roentgenogram the fragment also is rotated from above downward Without detachment of the soft tissues, the fracture is reduced and the fractured surfaces accurately apposed by means of a small

tenaculum or towel clip The normal contour of the articular surface of the humerus should be restored. The fragment is held in proper position and a *rustless steel nail 1.5 mm. in diameter is drilled from below* the external condyle upward and inward at an angle of 45 to 60 degrees. To insure an exact approximation and determine the position of the nail roentgenograms should be made prior to closure of the wound

After Treatment.—(See p 486)

Normal function is restored, with only slight if any disturbance in epiphyseal growth Poor results usually are occasioned by acceptance of a reduction which is less than perfect.



Fig. 359 —A Fracture of external condyle of humerus with typical rotation *of loose fragment* by common origin of extensor tendons *B* treated by open reduction and fixation with one wire nail. *C* Four years later no evidence of growth disturbance.

Fractures of the Humeral Condyles in Adults

Although the problem of growth disturbance does not arise in adults, the normal architecture of the joint should be restored as accurately as possible Incongruity of the articular surfaces following closed reduction frequently leads to limitation of motion pain disability and eventually to osteoarthritis.

In many cases, open reduction and internal fixation will afford more satisfactory apposition with better functional results than closed reduction The technic of operation is similar to that employed for children

RADIUS AND ULNA

Fractures of the bones of the forearm in which operative measures may be indicated are as follows (1) fractures of the olecranon, (2) fractures of the head of the radius, (3) fractures of the upper third of the ulna with dislocation of the head of the radius, (4) fractures of the shaft of the ulna, (5) fractures of the shaft of the radius, and (6) fractures of both bones of the forearm

Fracture of the Olecranon

In fractures of the olecranon *with separation of the fragments*, the internal fixation should be sufficiently secure to permit early resumption of motion The type of treatment depends upon the location and degree of comminution of the fracture, and upon the age of the patient. Three methods are available, each, in our opinion being indicated under different conditions

1 Fixation by a circumferential wire loop or figure-of-eight wire loop This method is applicable to isolated injuries of the olecranon process which are not comminuted and are well proximal to the level of the coronoid process.

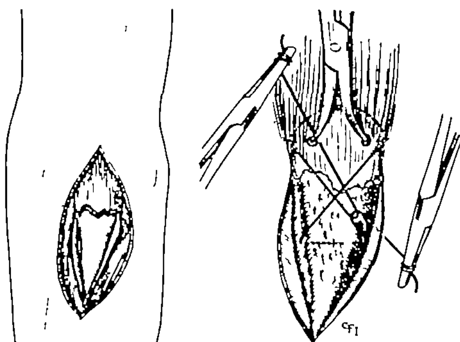


Fig. 360 —Repair of fracture of olecranon by wire loop. Wire passed through hole drilled in distal fragment and through triceps aponeurosis adjacent to bone. Figure-of-eight loop adds stability to fracture and prevents distraction and posterior bowing

By this technic, the olecranon process is restored to its normal position We feel that, under favorable conditions, the olecranon should not be discarded. In comminuted fractures, or if treatment must be delayed and the ends of the fragments have absorbed the procedure is not applicable under these circumstances, if the wire loop approximates the fragments snugly the trochlea is pinched between Further incongruity of the articular surface is likely to lead to a traumatic arthritis. A loosely applied loop may be followed by nonunion

2. Intramedullary fixation This method is particularly applicable to extensively comminuted fractures of the olecranon, such as those produced in side-swipe fractures, wherein the distal fragment and the head of the radius are dislocated anteriorly, rigid fixation is necessary to prevent recurrence of the dislocation. Because of the extreme comminution, a plate and screws are not suitable If a fracture of the shaft of the ulna is associated intramedullary fixation may be applied both to the fracture of the shaft and to the olecranon process.

3 Excision of the proximal fragment or fragments This form of treatment possesses two advantages Since the comminuted fragments are removed, the question of nonunion is obviated only the question of union of the tendon to the distal fragment remains. For the same reason the question of traumatic arthritis from incongruity of the articular surface is obviated to some extent. The use of the procedure is entirely contingent upon whether a sufficiently large portion of the olecranon can be left to form a stable base with the trochlea. Thus, it is not applicable to comminuted fractures which extend as far distally as the coronoid process Within the limits of its applicability the criticism may be offered that the proximal end of the olecranon process has considerable function and that the elbow is less efficient further the protection offered by the olecranon process to the posterior aspect of the elbow joint is lost. Our experience with this procedure is so limited that we are not prepared to argue effectively for or against its use To the present time, we have employed the method only for isolated comminuted fractures of the proximal half of the olecranon, and fractures wherein treatment is either delayed or nonunion is already established. It is particularly appropriate for patients 50 years of age or more, who do not require a ' heavy duty' elbow As our experience with this procedure increases, these indications may change In elderly individuals, a fibrous union following conservative measures may provide sufficient function.

Technic of Circumferential Wire Loop.—The incision is begun one inch above the olecranon process parallel with the outer border and carried downward a distance of three inches close to the outer border of the shaft of the ulna. After exposure of the line of fracture a hole is drilled in the lower fragment from side to side A rustless steel wire is passed through the hole in the lower fragment, then, by means of a curved needle, beneath the aponeurosis of the triceps muscle and around the tip of the olecranon. An assistant grasps the olecranon with towel clips or Ochsner forceps and exerts downward traction while the loop is twisted tightly Thus the same mechanical principle is applied in fractures of the olecranon as in the patella, i.e a circumferential loop is placed about the olecranon For the more distal fractures, this type of fixation may not provide adequate stability this can be easily determined by acute flexion of the elbow If the proximal fragment tends to angulate posteriorly, the wire loop may be quickly changed to form a figure-of-eight suture across the posterior aspect of the fracture site (Fig 360) This places the wire loop sufficiently subcutaneous to necessitate its removal at a later date.

After Treatment.—A right-angle posterior elbow splint is applied. Gentle active and passive motion and physical therapy are instituted after two weeks, the elbow being supported between exercises by a right-angle removable splint. Ordinarily all apparatus may be discarded at four weeks.

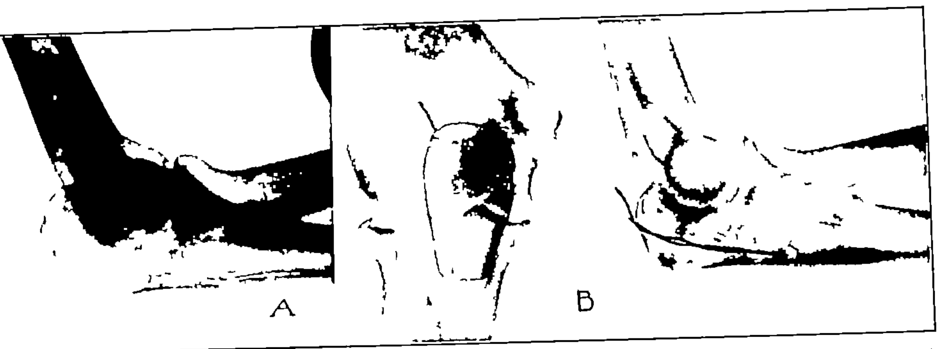


Fig 361 — A Fracture of olecranon process. B Fragments maintained in anatomic position by wire loop passed through drill holes in distal fragment and around olecranon process, through triceps aponeurosis.

If operation is carried out early and there are no complications, the end results are excellent. Six months or even a year may elapse however before the maximum degree of function returns. Pronation and supination are *seldom diminished to* an appreciable extent, though flexion and extension may be limited. The rapidity with which motion increases, as well as the ultimate range secured depends upon the extent of injury to the joint surfaces and *whether or not traumatic* arthritis develops.

Technic of Intramedullary Fixation.—The fracture site is exposed as described above. For isolated fractures of the olecranon process, a five-inch *Knowles* pin provides excellent fixation. With the forearm across the chest and the elbow at a right angle, the Knowles pin is introduced into the olecranon process until its point emerges at the fracture site in line with the intramedullary canal of the ulna. The fracture is then reduced and the pin is drilled down the intramedullary canal of the distal fragment. Comminuted fractures should not be approximated too snugly otherwise the olecranon process will pinch the trochlea.

If the comminuted fracture of the olecranon is associated with a fracture of the shaft of the ulna, the intramedullary pin is introduced in a retrograde manner (p 504) an assistant meanwhile maintaining reduction of the olecranon fracture.

Excision of the Olecranon

McKeever and Buck note that the stability of the elbow joint is quite satisfactory as long as the coronoid process and the vertical distal face of the trochlear notch are preserved, that a fragment which constitutes as much as 80 per cent of the semilunar notch may be excised without deleterious effects.

Because some of their patients noted that the ulnar nerve could be traumatized more easily after excision of the olecranon these authors advised that the nerve should be isolated at the time of the excision and transplanted forward.

Technic (McKeever and Buck)—*A longitudinal* incision that extends 10 cm above and below the tip of the olecranon is made through the skin and fascia. Subsequently the ulnar nerve is exposed and isolated. A U shaped incision is then made in the triceps aponeurosis with the base of the U slightly distal to the fracture (Fig 362). The olecranon, along with the triceps flap is *turned* proximally, by sharp dissection, the bone is removed from the tendon and the proximal end of the shaft of the ulna is smoothed and shaped. With the aponeurosis under slight tension and the elbow extended, a few sutures of *chromic* cat gut are passed through the sides of the tongue into the medial and lateral fascial structures from which it was freed. Subsequently the distal end of the aponeurosis is sutured to overlapping flaps of the *periosteum and fascia* from the ulna. Interrupted sutures of chromic catgut, with overlapping and imbrication of the distal end of the aponeurosis, completes the procedure on the fracture. *The ulnar nerve is transposed to the volar aspect* of the medial condyle, if desired. Before the skin is closed, the tension on the tongue of fascia is noted as the elbow is flexed. Ordinarily tension will not be extreme at 70 degrees.

After Treatment.—*The joint is* immobilized in a posterior molded plaster splint, with the elbow at 110 degrees. Mobilization is begun at three weeks, the arm being carried in a sling for an additional ten days.

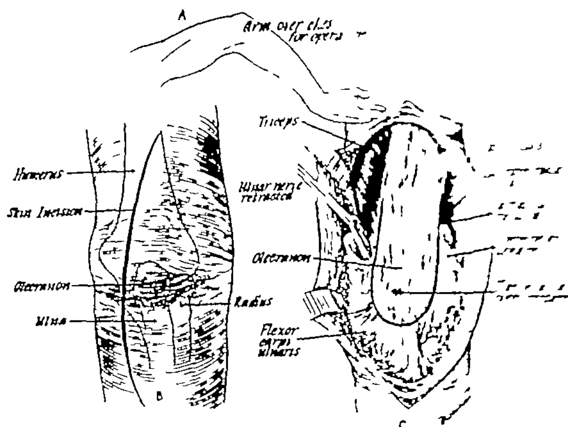


Fig. 362.—*A* Excision of fragment for fracture of olecranon proce... incision. *C*, U-shaped flap of triceps aponeurosis turned proximally (Fr... and Buck, R. M. J. A. M. A. 135: 1 1947.)

Fig. 363.—Same a Fig. 362. *D* Fragment of bone removed ... sharp di section. Distal fragment reshaped. *G* Ulnar nerve tr... aponeurosi repaired. (From McKeever F. M., and Buck, R. M.

Fractures of the Head and Neck of the Radius in Adults

The majority of fractures of the head of the radius may be treated successfully by conservative methods Slight degrees of displacement are compatible with excellent function Key states that any fracture which causes the head of the radius to become egg shaped, or interferes with the regular smooth contour of the inner half of the circumference will be followed by limitation of rotation of the forearm, pain incident to motion and eventually a traumatic arthritis of the proximal radio-ulnar and radiohumeral joints. A similar outcome may be expected if fractures of the neck of the radius are allowed to unite in malposition, i.e., oblique to the longitudinal axis. In general, the following types of fractures are not compatible with good function and thus necessitate surgical intervention *gross comminution of the head and neck* marginal fractures involving more than one-third of the articular surface particularly if the fracture is adjacent to the radio-ulnar joint loose fragments of the bone in the elbow joint, fractures of the neck of the radius with sufficient angulation to interfere with rotation. The last type is observed most often in children (p 495)

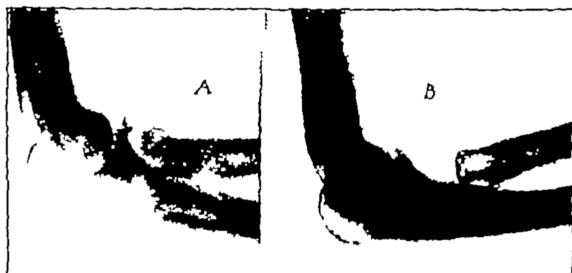


Fig. 344.—*A* Comminuted fracture of head of radius involving articular surface. *B* Six months after excision. Many fractures of this type are followed by proliferative changes with subsequent limitation of motion, particularly if excision of the head of the radius is delayed.

As a rule surgical treatment consists of total excision of the head and neck. The procedure should be carried out early In adults, the head of the radius is not a particularly important structure, so far as the elbow joint is concerned the joint will be relatively stable without this structure. This, however is not true in children. It is the general opinion that the results of partial excision of the head of the radius are poorer than those of total excision. On rare occasions, partial excision may be indicated in the presence of a small chip fracture which is loose in the elbow joint and if more than two-thirds of the head of the radius is undamaged.

Excision of Head of Radius.—The incision (p 183) is made along the posterolateral aspect of the shaft of the radius, beginning two inches below the head and extending upward over the head and external condyle of the humerus. In

the distal portion of the incision dissection is carried down between the extensor carpi ulnaris and extensor digitorum communis muscles to the periosteum, thence continued upward over the remains of the head, through the posterior capsule of the joint to the posterior surface of the external condyle All loose particles of bone are removed The periosteum is next reflected from the shaft down to the level of the bicipital tuberosity At this point, the shaft is divided transversely with a Gigli saw or chisel and the upper extremity of the radius is removed The remains of the orbicular ligament are resected and every particle of periosteum is excised with painstaking care to restrict subsequent formation of new bone to a minimum The adjacent soft tissues are sutured over the raw end of the bone. If the fracture is limited essentially to the head of the radius and the immediate portion of the neck, excision of the head of the radius proximal to the orbicular ligament may be possible.

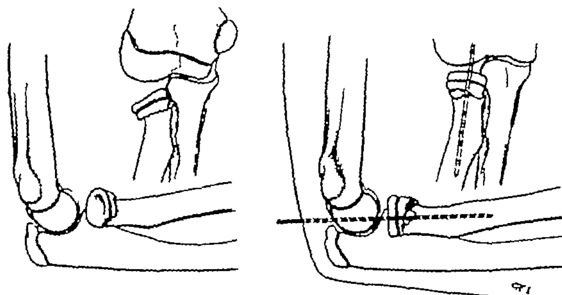


Fig. 364.—Typical deformity of fracture of neck of radius in a child. By ordinary means, internal fixation is quite difficult Kirschner wire passed through external condyle of humerus, head of radius, and into shaft of radius simply and effectually immobilizes fragment. The wire is removed 14 to 18 days postoperatively

After Treatment.—The arm is placed in a right angle posterior elbow splint. On the tenth day postoperatively the stitches are removed and active and passive motion and physical therapy are instituted

When this procedure is carried out early relatively normal function may be restored in a high percentage of cases, only a slight relaxation on the outer side of the elbow joint will remain Regardless of how carefully the operation is executed the results will not be entirely satisfactory in many cases as rotation is often limited by excess bone formation or scar tissue If an insufficient amount of bone is removed, or if the operation is delayed until osseous proliferation is well advanced, a poor result is more likely, motion in the elbow may be extremely limited or there may be synostosis between the radius and ulna

Fractures of the Neck of the Radius in Children

In the survey of fractures about the elbow by Boyd and Altenberg those of the neck of the radius represented less than 5 per cent of the group The head of the radius was involved in only 2 of the 34 patients. Usually the neck

Fractures of the Head and Neck of the Radius in Adults

The majority of fractures of the head of the radius may be treated successfully by conservative methods. Slight degrees of displacement are compatible with excellent function. Key states that any fracture which causes the head of the radius to become egg-shaped, or interferes with the regular smooth contour of the inner half of the circumference, will be followed by limitation of rotation of the forearm, pain incident to motion, and eventually a traumatic arthritis of the proximal radio-ulnar and radiohumeral joints. A similar outcome may be expected if fractures of the neck of the radius are allowed to unite in malposition, i.e., oblique to the longitudinal axis. In general the following types of fractures are not compatible with good function and thus necessitate surgical intervention: gross comminution of the head and neck; marginal fractures involving more than one-third of the articular surface, particularly if the fracture is adjacent to the radio-ulnar joint; loose fragments of the bone in the elbow joint; fractures of the neck of the radius with sufficient angulation to interfere with rotation. The last type is observed most often in children (p. 495).

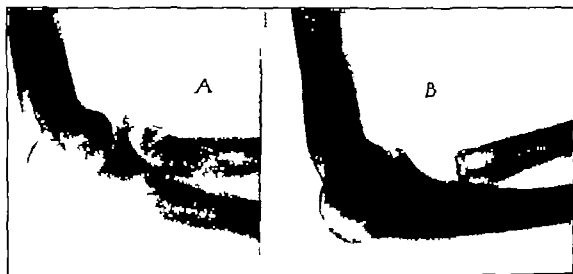


Fig. 364.—A, Comminuted fracture of head of radius involving articular surface. B, Six months after excision. Many fractures of this type are followed by proliferative changes with subsequent limitation of motion, particularly if excision of the head of the radius is delayed.

As a rule, surgical treatment consists of total excision of the head and neck. The procedure should be carried out early. In adults, the head of the radius is not a particularly important structure, so far as the elbow joint is concerned; the joint will be relatively stable without this structure. This, however, is not true in children. It is the general opinion that the results of partial excision of the head of the radius are poorer than those of total excision. On rare occasions, partial excision may be indicated in the presence of a small chip fracture which is loose in the elbow joint, and if more than two-thirds of the head of the radius is undamaged.

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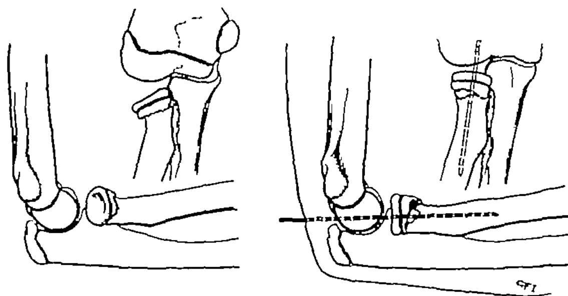


Fig 365.—Typical deformity of fracture of neck of radius in a child. By ordinary means, internal fixation is quite difficult Kirschner wire passed through external condyle of humerus, head of radius, and into shaft of radius simply and effectually immobilizes fragment. The wire is removed 14 to 18 days postoperatively

After Treatment.—The arm is placed in a right angle posterior elbow splint On the tenth day postoperatively the stitches are removed and active and passive motion and physical therapy are instituted.

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Fractures of the Neck of the Radius in Children

In the survey of fractures about the elbow by Boyd and Altenberg those of the neck of the radius represented less than 5 per cent of the group The head of the radius was involved in only 2 of the 34 patients. Usually the neck

was fractured just distal to the epiphyseal line of the head, the proximal fragment being displaced laterally and anteriorly or laterally and posteriorly

If the head of the radius is materially displaced and reduction cannot be accomplished by closed methods, open reduction is indicated. *Removal of the head of the radius in a child is contraindicated, as a cubitus valgus deformity with disturbance in function of both elbow and wrist will ensue.*

Technic.—The fracture of the head of the radius is exposed by a posterolateral incision (p 183) The fracture is simply reduced by the use of Ochsner forceps. *Frequently one of the cortices is either "greensticked," or the fracture is partially impacted.* In the majority of cases, mere replacement of the fragments, with a slight impaction to maintain their position, is sufficient. Prior to closure, the most stable position of the fracture should be established ordinarily this will be a position of midpronation and supination with the elbow rather acutely flexed to 45 degrees. If necessary, internal fixation by means of an intramedullary wire (Fig 365) may be employed The metallic fixation should be removed 14 to 18 days later

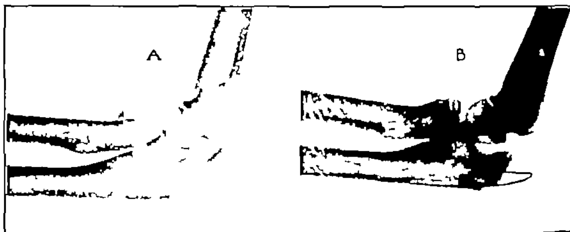


Fig. 364.—*A* Fracture of head of radius and of olecranon. *B*, After open reduction and mere replacement of head of rad us in normal position no internal fixation used. Olecranon fixed by wire loop united in satisfactory position.

After Treatment.—The elbow is immobilized in the most advantageous position by a posterior molded plaster splint After three weeks, a sling is substituted, and gradual active and passive exercises are begun.

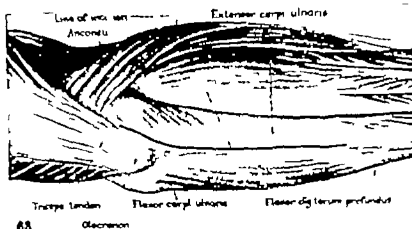
Occasionally motion of the elbow joint, particularly pronation and supination may be limited though, as a rule the results are quite satisfactory

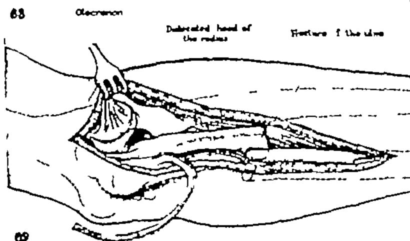
Fracture of the Upper Third of the Ulna, With Anterior Dislocation of the Head of the Radius (Monteggia Fracture)

This combination, known as Monteggia fracture, presents a most difficult mechanical problem. The subsequent discussion of this entity will be limited to fractures in adults. The problem in children *is slightly different, both as to* treatment and prognosis (p 500)

Even with the most effectual treatment, some degree of residual disability is likely With ineffectual treatment, the list of complications becomes formidable The ulna is usually fractured at the junction of the middle and upper third fractures in this region are notorious *for either slow union* malunion

or nonunion the fragments generally bowing toward the radial aspect of the forearm This deviation from the normal axial alignment of the ulna prevents accurate articulation between the trochlear surface of the humerus and the articular surface of the ulna The consequent incongruity will eventually lead





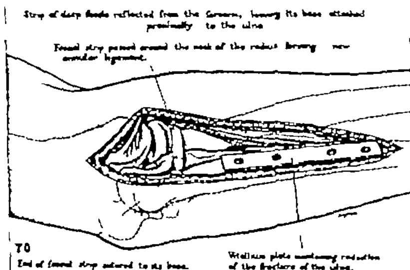


Fig. 367 —Speed and Boyd procedure for Monteggia fractures. Dislocation of head of radius and fracture of ulna exposed through one incision (Boyd) (From Campbell, W C, and Smith, H. Dean Lewis' Practice of Surgery Hagerstown, Md., 1940 W F Prior Co., Inc.)

Fig. 368 —Same as Fig. 367 Operative field exposed. Strip of fascia dissected free with its base at level of neck of radius. (From Campbell, W C., and Smith, H. Dean Lewis' Practice of Surgery Hagerstown, Md., 1940 W F Prior Co., Inc.)

Fig. 369 —Same as Fig. 367 Dislocation reduced and new orbicular ligament formed from fascial strip. Fracture of ulna immobilized by a plate. A bone graft would be preferable, as union takes place slowly in this location. (From Campbell, W C., and Smith, H. Dean Lewis' Practice of Surgery Hagerstown, Md., 1940 W F Prior Co., Inc.)

to restricted motion and a progressive traumatic arthritis. Changes of less importance may occur at the distal radio-ulnar joint. If the fragments of the ulna overlap producing shortening the dislocation of the head of the radius will recur. Because of this list of probable complications from closed methods, a primary onlay bone graft to the fracture is the surest and most effectual therapy. If the fracture involves the olecranon or the middle or distal third of the shaft of the ulna, metallic forms of fixation may be utilized.

The forces which produce the dislocation of the head of the radius more commonly produce a fracture of the shaft of the radius. Instead, the capsular structures and the orbicular ligament are torn or avulsed, allowing anterior displacement of the head of the radius from its normal articulation with the capitellum. Less often the dislocation may be posterior or lateral; rarely the head of the radius may be pulled out of an intact annular ligament. Unless the trauma is excessive the dislocation usually prevents fracture of the shaft of the radius. Occasionally the head of the radius is fractured as well as dislocated.

Most of the controversy over the treatment of this entity centers on the proper handling of the dislocation or fracture-dislocation of the head of the radius. Either of two courses may be pursued. (1) Reduction of the dislocation by closed measures followed by immobilization of the elbow in a rather acutely flexed position for ten to twelve weeks. Later if indicated, the orbicular ligament may be reconstructed or the radial head excised. (2) The alternative consists of reconstruction of the orbicular ligament or excision of the radial head at the time of the fixation of the ulna. We prefer the latter course. We cannot subscribe to the Watson-Jones contention that this will almost inevitably lead to ankylosis. In our experience, reconstruction of the orbicular ligament with early mobilization produces a far more satisfactory result than the prolonged immobilization incident to a more conservative approach.

Smith notes that in ten cases of Monteggia fractures, the orbicular ligament was either intact, or a torn ligament or capsule was interposed between the radial head and the capitellum or lesser sigmoid notch. Either of these two contingencies would prevent closed reduction of the dislocation of the head of the radius. This is contrary to the statement by Böhler that all Monteggia fractures can be treated by conservative methods.

Technic (J. S. Speed and Boyd).—The fracture of the ulna and the dislocation of the head of the radius may be adequately exposed by the Boyd approach (p. 187). The status of the orbicular ligament is first determined. Ordinarily the ligament is frayed and ruptured or avulsed so as to preclude suture. Rarely in children, the ligament may remain partially intact; in this event it may be slipped back over the head of the radius. As a rule reconstruction of a new ligament will be necessary. A strip of deep fascia one half inch wide and approximately four and one-half inches long is dissected from the muscles of the forearm. The proximal end of the strip is left attached to the proximal end of the ulna where the deep fascia blends with the periosteum at the lower end of the subcutaneous triangular space which forms the dorsal portion of the olecranon. The fascial strip is passed between the radial arch of the ulna and the tuberosity of the radius and thence around the neck of the radius. This step in the procedure will be accomplished with more facility and

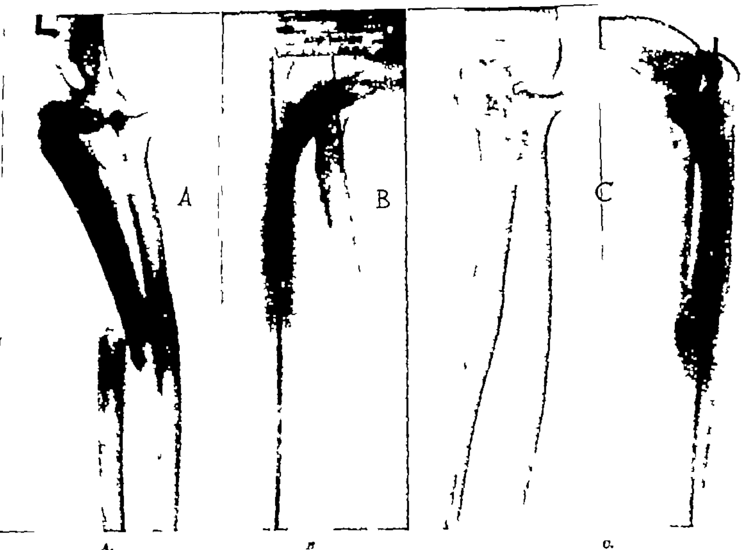


Fig. 370.—*A*, Monteggia fracture. *B*, Treated by intramedullary fixation of ulna. Recurrence of dislocation of head of radius prevented by Kirschner wire inserted through external condyle of humerus, across the joint into radius. *C*, Three and one-half months postoperatively normal radiohumeral articulation and solid union of fracture of ulna. Patient was eighteen years of age. This technic is too new to permit an estimate of its value.

less trauma if undertaken early in this procedure. The fragments of the ulna are then approximated and aligned, and fixed by means of an onlay bone graft. Finally, the new orbicular ligament is sutured snugly about the neck of the radius.

After Treatment.—With the forearm in midposition and the elbow at a right angle, a cast is applied from the axilla to the palm. The cast is bivalved to allow for swelling. After four weeks, gentle active and passive exercises may be instituted and carried out every three hours. In the interval between exercise periods, the arm is supported in a removable metal splint. External fixation is not discarded until the fracture of the ulna is firmly healed.

In 1940 Speed and Boyd surveyed 52 injuries of this type, 30 of which were relatively acute. Some of the patients have attained almost perfect function in the elbow; the majority, however, have some limitation of motion, particularly, supination and pronation. The operative management advocated above has effectually prevented angulation of the ulna and maintained reduction of the radial head. The results have been gratifying from both an anatomic and functional point of view.

Fractures of the Upper End of the Ulna With Anterior Dislocation of the Head of the Radius in Children

In children, the alignment and position of the ulna may be restored and the dislocation of the head of the radius reduced by manipulation. The extremity is then immobilized with the elbow at 45 degrees. The ulna angulates toward the radius, though this is not itself considered sufficient indication for surgical intervention. The angulation of the ulna will eventually be compensated by growth. If the dislocation of the head of the radius recurs, surgical intervention is warranted; the orbicular ligament is reconstructed, as described above for adults, and the fracture of the ulna immobilized by some form of metallic fixation.

Fractures of the Shaft of Radius and Ulna

If satisfactory alignment or fixation of fractures of either the radius or ulna, or fractures of both bones of the forearm, is not possible by conservative measures, open reduction is required. Frequently this cannot be determined until conservative measures have failed.

Although the rules concerning alignment, length, and position are less rigid than those for fractures involving joint surfaces or fractures adjacent to joints, they are certainly more exacting than for fractures of the humerus, femur or tibia. Preservation of the interosseous space between the radius and ulna is necessary to rotary movement. Contact of the radius with the ulna may be followed by a complete synostosis of the bone. In fractures of the middle half of the shaft of either bone, nonunion is often an additional complicating factor.

The intact bone frequently has an adverse effect upon a fracture of the other. The intact bone does not allow any settling or telescoping of the fragment; rather it tends to hold them apart; with slight angulation and with the natural absorption of the ends of the fragment, contact may be lost entirely and a nonunion may ensue. This is particularly true of isolated fractures of

the middle and distal third of the radius and the proximal and middle third of the ulna In fractures of both bones of the forearm, both fractures are frequently unstable and proper alignment and position are maintained with difficulty

It is impossible to establish any definite rules regarding the indications for open reduction of fractures of the forearm Consequently, we shall have to confine ourselves to the statement that assuming the displacement is complete, open reduction is usually indicated in the following fractures (1) isolated fractures of the middle half of the shaft of the radius, particularly the middle and distal third (2) isolated fractures of the shaft of the ulna in the region of the middle and proximal third (3) oblique torsional comminuted or segmental fractures of both bones of the forearm

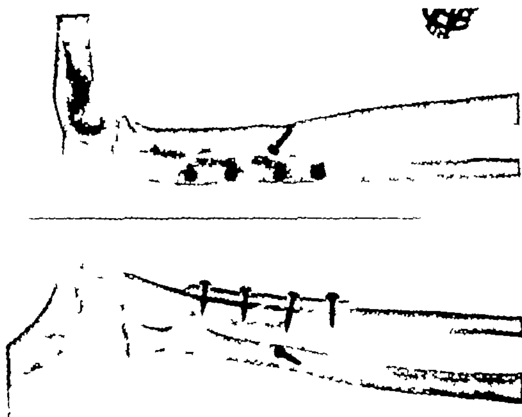


Fig 371 —Fracture of both bones of forearm treated by autogenous onlay bone graft to ulna and transfixion screw through oblique fracture of radius. At ten weeks, there is beginning amalgamation of the graft with the ulna. Note absorption of ends of fragments with fixation by a metal plate and screws, such a fracture might fail to unite.

Because of the strong possibility of nonunion the choice of internal fixation material must be given more than ordinary study For torsional or long oblique fractures transfixion by screws are quite satisfactory (p 367) For short oblique fractures, a plate and screws may serve the purpose In comminuted or transverse fractures, we have found that the use of plates and screws is frequently followed by nonunion Under these circumstances, the use of a primary onlay bone graft should be seriously considered. As time goes on we are employing fewer metal plates and more bone grafts. By this method, a high percentage of fresh fractures will unite primarily Were it not for the magnitude of the procedure the prolonged convalescence incident to removal

of a graft from the tibia, and the jeopardy to a normal extremity we would probably utilize this measure routinely for many fractures of the forearm. The bone bank may obviate some of these disadvantages. Primary bone-graft procedures, of course, should be limited to closed fractures.

We are not at present in a position either to approve or disapprove of the use of intramedullary fixation for the radius and ulna. We have used it sufficiently, for compound fractures, to know that it provides a relatively simple and efficient means of fixation with minimum trauma (Fig 375) Our series, however, is too small to permit us to determine the percentages of union and non union.

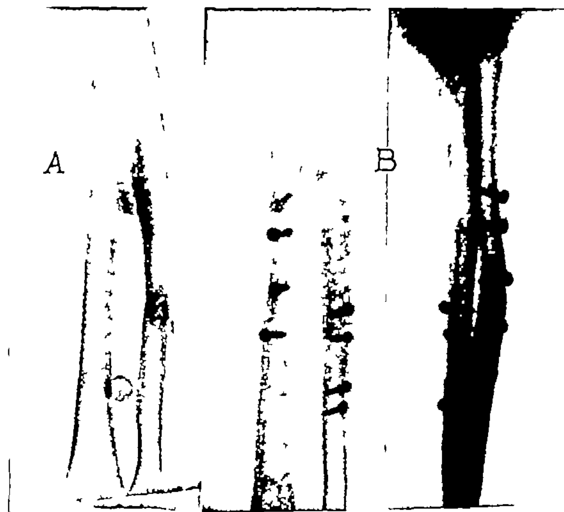


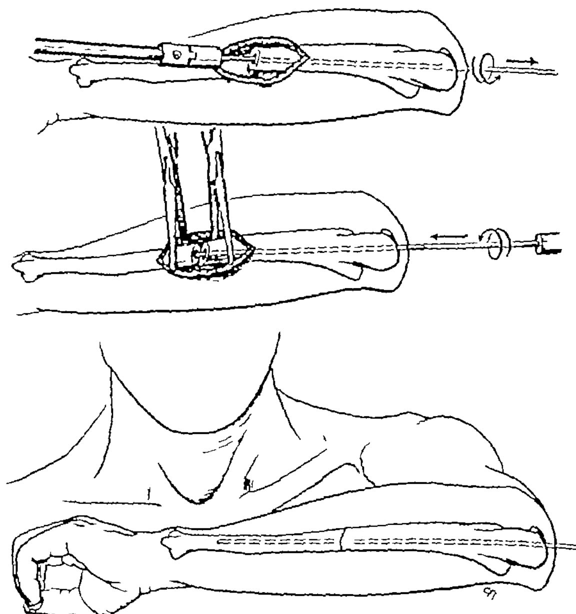
Fig. 372.—*A* Fracture of both bones of forearm treated by bone grafts from bone bank in lieu of metal plates. *B* Ten weeks postoperative. By this technic, a high percentage of forearm fractures may be expected to unite.

The ulna may be exposed by an incision along the subcutaneous border Exposure of the radius is considerably more difficult (p 182) Care must be exercised to avoid injury to the radial nerve in exposure of the upper third of the radius

Intramedullary Fixation of Fractures of the Forearm

Fractures of either the radius or ulna or both bones are amenable to intra medullary fixation, particularly the ulna. Intramedullary fixation may be used

in any fracture of the latter bone from the level of the coronoid process to the distal three inches, and in the radius, in an area *between the proximal end or head* and the distal three inches. When both bones are fractured, the ulna should be stabilized first. Fixation of the ulna may provide sufficient stability to obviate the necessity of fixation of the fractured radius, particularly if the *radial fracture is in good position* and in the proximal third. If the Küntscher



11

Fig. 372.—Intramedullary fixation of ulna. Note retrograde method of insertion. Küntscher U shaped pin may be inserted in the same manner

pins are used for the radius, the minimum length should be 16 cm. and the maximum length 22 cm., and the diameters from 4 mm. to 5 mm. For the ulna, the minimum length is 14 cm. and maximum length 20 cm., and the diameters should be 3.5 mm and 4 mm. The exact length of the pins should be determined preoperatively. If Kirschner wires are chosen, a standard length may be employed, the excess being snipped off after the operation is completed. For the

ulna, a relatively large sized wire, similar to a Smith Petersen guide pin is satisfactory For the radius a slightly smaller wire is sufficient

Technic (For the Ulna) —With the forearm resting across the chest, an incision is made over the fracture site and the fracture exposed. A round rod is best used in a retrograde fashion the distal end of the *proximal fragment*

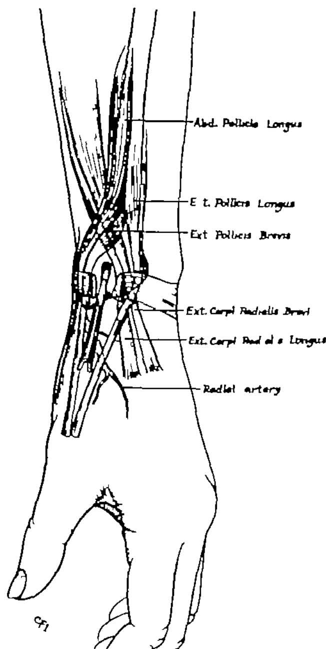


Fig. 374.—Intramedullary fixati n of fractures of radius. Pin enters bone just proximal to *anatomic snuff box.*

is raised out of the wound the pointed end of the rod is drilled into the intra*medullary canal of the proximal fragment* and through the olecranon process until the end pierces the skin. The drill is then reversed and the rod withdrawn until the blunt end of the rod is level with the fracture site. The fracture is then reduced and the rod drilled into the *intramedullary canal*. The end of the rod is nipped off short so that its end is buried in the triceps tendon of the distal portion of the bone.



Fig. 375.—*A*, Segmental comminuted compound fracture of radius and comminuted fracture of shaft of ulna sustained when forearm was caught in belt. Soft tissue injuries precluded primary bone graft procedures. *B* Fragments of radius strung like beads on a Kirschner wire. Pin of heavier construction passed down medullary canal of ulna. *C* Proximal fracture of radius and fracture of ulna united at 1 weeks. Distal fracture of radius ununited, treated by bone graft at 16 weeks.

If the Küntscher pin is utilized, a small incision is made over the olecranon process. With a drill the intramedullary canal is opened. A straight Küntscher pin is introduced into the intramedullary canal of the proximal fragment, the fracture is reduced and the pin is then continued into the distal intramedullary canal.

After Treatment.—Isolated fractures of the ulna which do not involve the olecranon process require immobilization only until the surgical wound heals. Thereafter a splint is applied and the patient is allowed to resume restricted intermittent exercises and use of the extremity.



Fig. 376.—Simple fracture middle third of radius, treated by intramedullary pin.

Technic (For the Radius).—An incision two inches long is made longitudinally over the distal aspect of the radius and the bone is exposed at the styloid process between the extensor carpi radialis longus and the extensor pollicis brevis, i.e. the anatomic snuff box. With a drill and chisel, a slot one inch long is made in the radius. The slot must be sufficiently large to allow a very flat angle. If a Kirschner wire is used, the distal two inches should be bent to an angle of 10 or 20 degrees. Either the guide wire or a Küntscher pin should be introduced at an angle as flat as possible. Considerable difficulty may be experienced in introducing the wires through the intramedullary portion of the distal fragment. The fracture site is next exposed, the fracture reduced and the intramedullary pin introduced across the fracture site into the proximal fragment. In order to prevent interference with tendons at the wrist joint,

a Küntscher pin must be driven in practically flush with the bone A Kirschner wire may be bent on itself to form a small circle the end of the wire being embedded in the slot.

In a limited number of cases we have recently inserted the fixation through a slot in the cortex just proximal to Lister's tubercle

After Treatment.—Fixation of a fractured radius by an intramedullary pin is seldom so stable that one may entirely dispense with immobilization As a rule, a cast is applied from the axilla to the palm and maintained intact for a period of eight weeks Active exercises may usually be instituted at this time The pin should not be removed until the fragments are solidly united as demonstrated by roentgenograms, which is generally from four to six months

Colles Fracture

Open reduction is indicated only in the presence of excessive crushing of the bone with extreme radial shortening Moreover, the patient should be less than forty five years of age Crushing of cancellous bone at the line of fracture is commonly seen in individuals beyond this age A satisfactory reduction practically always can be secured by manual force but frequently cannot be maintained the usual result is a restoration of the normal angle to the articular surface though a slight radial shortening The operative procedure is identical to that described for malunited Colles fractures (p 578) fixation being secured by an obliquely placed metal pin that passes from the styloid process across the fracture into the opposite cortex.

CARPAL AND METACARPAL BONES

Fractures of the Carpal Bones

Fracture of the scaphoid is observed more often than of any other of the carpal bones. If immobilization is instituted immediately and prolonged sufficiently a satisfactory result usually may be secured Essentially the only occasions for open reduction of the scaphoid bone occur (1) when the fragments are so extensively comminuted that a traumatic arthritis of the wrist joint is a certainty In this event, the ulnar fragments should be excised (p 698) (2) when reduction is inadequate, a bone-graft procedure (p 699) as for nonunion, is indicated.

FRACTURE OF THE METACARPAL BONES

Fractures of the neck or shaft of a metacarpal bone should be reduced by operation only when the fragments are grossly displaced and more conservative measures, such as skeletal traction or pulp or skin traction are likely to be inadequate.

Intramedullary fixation provides a satisfactory form of immobilization. In view of the danger of infection and interference with finger exercises incident to protrusion of a wire through the skin the wires are not inserted in a retrograde manner as for the metatarsal bone In a few cases, we have allowed the pin to protrude from the lateral or medial side of the neck of the metacarpal and thence through the skin The technic described below is preferable. A transarticular introduction of the wire is not advisable.



Fig. 377.—Fracture of styloid process of radius with dorsal subluxation of wrist joint, treated by open reduction and two intraosseous bone pegs.

Technic.—Through a longitudinal curved incision, the fracture site and base of the affected metacarpal bone are exposed A hole is made in the base of the bone into the intramedullary canal, the drill being inserted at a perpendicular angle to the bone and gradually flattened out to an obtuse angle Two or three holes drilled in this manner make a satisfactory slot. A Kirschner wire is then introduced into the proximal fragment at a rather flat angle, until it emerges at the fracture site Thereafter, the fracture is reduced and the intramedullary pin drilled into the distal fragment In fractures involving only the neck of the bone, the wire should approach the articular surface of the head, otherwise, fixation will be insecure The ends of the wire may be embedded into the slot or may be curved on themselves, the pointed end penetrating the slot. The ends must not protrude sufficiently above the bone to cause irritation of the adjacent tendons or slough through the skin Since the wire should be removed later (usually at 8 to 10 weeks) the end should be left sufficiently prominent to permit its removal without difficulty

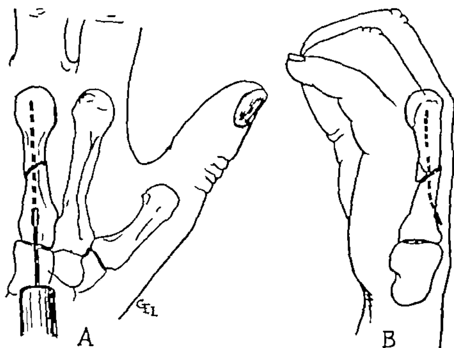


Fig. 378.—A Intramedullary metallic pin fixation of metacarpal bone is inserted through slot at base, rather than violate the proximal finger joint. B Small segment of wire left subcutaneous to facilitate removal at four weeks.

In lieu of the above technic, a small homogenous peg may be inserted into the intramedullary canal of the proximal fragment and the distal fragment placed over the protruding end of the peg This also provides efficient fixation.

After Treatment.—In isolated fractures of a single metacarpal bone in the middle half of the shaft, immobilization may be omitted. In fractures of the distal third of the metacarpal bone a molded plaster splint should be worn for three weeks.

References

Adams, A W Fractured Lumbar Spine with Unilateral Dislocation Brit. J Surg 25 632, 1938.

Aitken A. P., and Childress, H. M. Intra Articular Displacement of the Internal Epicondyle Following Dislocation J Bone & Joint Surg 20 161, 1938

Albee Fred H.: Injuries and Diseases of the Hip. Surgery and Conservative Treatment, New York, 1937 Paul B Hoeber Inc.

— Treatment of Fracture of the Neck of the Femur Am. J Orth. Surg 16 493 1918.
—: Bone Graft Surgery, Philadelphia, 1915 W B Saunders Co
— Bone-Graft Peg Operation, Surg Clin. John B. Murphy 2 465, 1913
Altemeier W A., and Furste, W L. Gas Gangrene, Internat. Abstr Surg 84 507, 1947
Arnold L A. Different Methods of Internal Fixation of Fractures, Southern M. J 25 971 1932
Barr J S. The Treatment of Fracture of the External Tibial Condyle (Bumper Fracture) J A. M. A. 115 1683, 1940.
Bentley F H. and others Treatment of Compound Fractures by Early Wound Suture and Penicillin, Lancet 1 232, 1945.
Berkman, E. S. and Miles, G H.: Internal Fixation of Metacarpal Fractures Exclusive of the Thumb J Bone & Joint Surg 25 816, 1943.
Bisgard, J D Fractures Involving the Epiphyseal Cartilage West. J Surg. 46 412, 1938.
Blair H. C. Comminuted Fracture and Fracture-Dislocations of the Body of the Astragalus Operative Treatment, Am J Surg 59: 37 1943.
Blodgett, W E., and Fairchild, R. D Fractures of the Patella, Result of Total and Partial Excisions of the Patella for Acute Fractures, J A M. A 106 2121 1936
Blount W P Blade Plate Internal Fixation for High Femoral Osteotomies, J Bone & Joint Surg 25 319 1943.
Böhler L.: Diagnosis, Pathology, and Treatment of Fractures of the Os Calcis, J Bone & Joint Surg 13 75 1931
— The Treatment of Fractures, Wien 1929 Wilhelm Maudrich.
Böhler L. Die Technik der Knochenbruchbehandlung im Frieden und im Kriege, vol. 1, Vienna, 1945 Wilhelm Maudrich
Bonnot G Two Cases of Atlanto-Axial Dislocation Without Spinal or Medullary Symptoms *Failure of Orthopedic Treatment Bolting With an Albee Graft as a Precaution*, Internat. Abstr Surg 58 358 1934 (Abstracted from Bull. et mém. Soc. nat. de chir 59 1206, 1933)
Bosworth, D M.: Fracture-Dislocation of the Ankle with Fixed Displacement of the Fibula Behind the Tibia, J Bone & Joint Surg 29 130 1947
Boyd H. B., and Altenberg A. R. Fractures About the Elbow in Children, Arch. Surg 49 213, 1944.
Boyd H B., and George I L. Complications of Fractures of the Neck of the Femur J Bone & Joint Surg 29 13 1947
Boyd, H. B. and Knight, R. A. Fractures of the Astragalus, South. M. J 35 160 194–
Boyd J S. K. Tetanus in the African and European Theaters of War 1939-1945, Lancet 1 113 1946.
Breck L. W., and Basom, W C.: The Dual Plate No Cast, Internal Fixation of Shaft Fractures, South. M J 37 582 1944
Brewster W R. Internal Fixation in Fractures of the Hip Am. J Surg 30 420, 1935.
Brooke R The Treatment of Fractured Patella by Excision A Study of Morphology and Function *Brit. J Surg 24 733 1936-37*
Burgess E.: Fractures of the Ankle, J Bone & Joint Surg 26 721 1944
Burns B H. and Young R. H. Compound Fractures of the Femur Treated with the Aid of Penicillin, Lancet 1 236 1945
Campbell Willis C Fractures in and about the Neck of the Femur Minnesota Med. 15 654, 1932.
— Fractures of the Patella, South. M. J 28 401, 1935.
— The Practical Application of Physiological Principles in Treatment of Fractures, J M. A. Alabama 6 125 1936.
— Internal Fixation in Fractures of the Neck of the Femur Ann. Surg 105 939 1937
Campbell, W C. Arthroplasty of the Elbow Ann. Surg 76 615 1922.
Campbell, Willis C., Orr, H. Winnett, and Osgood, Robert B.: Report of a Commission Appointed by the American Orthopaedic Association to Study End Results of Intracapsular Fractures of the Neck of the Femur J Bone & Joint Surg 12 966 1930.
Campbell, W C., and Smith, H. Dean Lewis Practice of Surgery Hagerstown, Md., 1941 W F Prior Co, Inc.
Carrell, W B. End Results in 100 Fractures Treated by Internal Removable Fixation J Bone & Joint Surg. 18 409 1936.
Carrell B., and Carrell, W B Fractures in the Neck of the Femur in Children with Particular Reference to Aseptic Necrosis, J Bone & Joint Surg 23 225 1941.
Christopher, F Indications for Open Reduction of Fractures, Western J Surg 40 110, 1932.
Cleveland, M., Bosworth D M., and Thompson, F R. Intertrochanteric Fractures of the Femur A Survey of Treatment in Traction and by Internal Fixation, J Bone & Joint Surg 29 1049 1947

Cleveland, M., and Grove J A. Delayed Primary Closure of Wounds With Compound Fractures, J Bone & Joint Surg 27 452 1945
Cone W., and Turner W G: The Treatment of Fracture-Dislocation of the Cervical Vertebrae by Skeletal Traction and Fusion J Bone & Joint Surg 19 584 1937
Conn, H R: The Treatment of Fractures of the Os Calcis J Bone & Joint Surg 17: 392 1935
Cotton Frederic J: Dislocations and Joint Fractures, Philadelphia 1910, W B Saunders Co.
Crutchfield W G Skeletal Traction for Dislocation of the Cervical Spine South. Surgeon 2 156, 1933
— Further Observations on the Treatment of Fracture Dislocations of the Cervical Spine With Skeletal Traction, Surg Gynec. Obst. 63 513 1936.
— Treatment of Injuries of the Cervical Spine, J Bone & Joint Surg 20 696 1938
Cubbins, W R., et al.: Fractures of the Lateral Condyle of the Tibia. Classification, Pathology and Treatment, Surg Gynec. Obst. 59 461 1934
Daland, E. M.: A Study of Two Hundred and Thirty-Six Compound Fractures Treated at the Massachusetts General Hospital New England J Med. 210 983 1934
Darrach Wm. Disasters Following Operative Treatment of Fractures, Ann. Surg 90 595 1929
—: Open Treatment of Fractures, S Clin North America 11 577, 1931
Darrach, W: Compound Fractures, Arch. Surg 40 821 1940
Davis, A. G., and Fortune, C. W Compound Fractures, J Bone & Joint Surg 25 97 1943.
Dobbie R. P and Ryerson, S: The Treatment of Fractured Patella by Excision, Am. J Surg 55 339 1942.
Dunlop, J: Transcondylar Fractures of the Humerus in Childhood J Bone & Joint Surg 21 59 1939
Eastwood, W J., and Jefferson, G Discussion on Fractures and Dislocation of the Cervical Vertebrae, Proc. Roy Soc. Med. 33 651 1939
Eastwood, W J Fracture of the Os Calcis, Brit. J Surg 25 636 1938.
Ettorre, M. Results of the Treatment of Recent Fractures of the Neck of the Femur With Subtrochanteric Osteotomy, Third Congress Internat. Soc. Orthop Surg., 1936, p 573
Fitcher W R. Fracture of the Scapula Requiring Open Reduction. Report of a Case J Bone & Joint Surg 21 459 1939
Gaenslen, F J: Subcutaneous Spike Fixation of Fresh Fractures of the Neck of the Femur J Bone & Joint Surg. 17 739 1935.
— Fracture of the Neck of the Femur Sir Robert Jones Lecture in Orthopedic Surgery J A M. A. 107 105 1936
Gallie Wm E. Skeletal Traction in the Treatment of Fractures and Dislocations of the Cervical Spine Ann. Surg 106 770 1937
Gallie, W E. Fractures and Dislocations of the Cervical Spine Am J Surg 46 495 1939
Gallie, Wm. E., and LeMesurier, A B: The Transplantation of the Fibrous Tissues in the Repair of Anatomical Defects, Brit. J Surg 12 289 1924.
Garlock, J H. The Treatment of Compound Injuries of the Extremities, Ann. Surg 87 3_1 1928
Glenn, F Tetanus, A Preventable Disease Including an Experience With Civilian Casualties in the Battle for Manila (1945) Ann. Surg 124 1030 1946
Graham, W T., and Faulkner D M. Astragalectomy for Fractures of the Astragalus, Ann. Surg 89 435 1929
Gurd, F B: The Treatment of Compound Fractures, J Bone & Joint Surg 15 327 1933.
Hübler C. Die Stabile Osteosynthese, Munich Berlin 1944, J F Lehmann.
Hampton, O P., Jr Reparative Surgery of Compound Battle Fractures in the Mediterranean Theater of Operations Ann. Surg 122 _89, 1945
Harmon, P H., and Baker D R.: Fracture of the Scapula with Displacement, J Bone & Joint Surg 25 834 1943.
Harper S. B A Report of 54 Cases of Tetanus Complicating War Wounds, Wisconsin M J 46 900 194
Harris R. L: War Wounds The Present Status of Their Treatment, Canad. M. A. J 52 450, 1945.
Harris, R. I. Fractures of the Os Calcis; Their Treatment by Tri Radiate Traction and Subastragalar Fusion, Ann. Surg 124 1082, 1946.
Hart, V L. Reduction of Supracondylar Fracture in Children, Surgery 11 33 1942.
Haxton, H. A. The Function of the Patella and the Effects of its Excision, Surg., Obst. & Gynec. 80 389 1945
Hedrick, D W., Hawkins, F B., and Townley C. O Primary Arterial Injury Complicating Extremity Fractures, J Bone & Joint Surg 29 738, 1947
Henderson, M. S. Fractures From an Operative Viewpoint Radiology 12 214, 1929
—: Internal Fixation of Fractures of the Neck of the Femur Arch. Surg 35 419, 1937
Henry M. O Intracapsular Fractures of the Hip. A New Device for Lateral Osteosynthesis J Bone & Joint Surg 16 168 1934.

Hermann, O J: Conservative Therapy for Fracture of the Os Calcis, J Bone & Joint Surg 19 709 1937
Hermann, O J: The McMurray Osteotomy for Nonunited Hip Fractures, New England J Med. 232 186 1945.
Horwitz, T., and Lambert, R. G Patellectomy in the Military Service. Report of 19 Cases, Surg., Gynec. & Obst. 82 423, 1946
Inclan, A. Fracturas de Monteggia, Cir ortop. y traumatol. 2 203 1934
— Fracturas de Monteggia, Cultural S. A., Habana, 1935
Jewitt, E. L. One-Piece Angle Nail for Trochanteric Fractures, J Bone & Joint Surg 23 803 1941.
Jeffrey J S., and Thomson S Gas Gangrene in Italy Study of 33 Cases Treated With Penicillin, Brit. J Surg (supp.) 32 159 1944.
Jones, L.: The Shoulder Joint—Observations on the Anatomy and Physiology, With Analysis of Reconstructive Operation Following Extensive Injury Surg., Gynec. & Obst. 75 433 1942.
Johansson, Sven Zur Technik der Osteosynthese der Fract. colli femoris, Zentralbl. f Chir 59 2019 1932.
—: On the Operative Treatment of Medial Fractures of the Neck of the Femur Acta orthop Scandinav 3 362 1932.
— Operative Treatment and Results in Fracture of Neck of Femur Brit. M. J 2 361 1937
Kahn, E. A., and Yglesias, L. Progressive Atlanto-Axial Dislocation, J A. M. A. 105 348, 1935
Key J A. Wire Fixation of Fractures of the Proximal Third of the Humerus, Arch. Surg. 46 678 1943.
Key J A. Treatment of Fractures of the Head and Neck of the Radius, J A. M. A. 96 101, 1931.
Key John Albert, and Conwell, H. Earle The Management of Fractures, Dislocations, and Sprains, ed. 4, St. Louis, 1946 The C. V Mosby Co.
King B. B. Resection of the Radial Head and Neck An End Result Study of Thirteen Cases, J Bone & Joint Surg 21 839 1939
Knight R. A Treatment of Fractures of the Tibial Condyles, South. M. J 38 246, 1945.
Knowles, F L. Fractures of the Neck of the Femur Wisconsin M. J 35 106, 1936.
— Personal communication.
Kolodny A. The Periosteal Blood Supply and Healing of Fractures. Experimental Study J Bone & Joint Surg 5 698, 1923.
— The Architecture and the Blood Supply of the Head and Neck of the Femur and Their Importance in the Pathology of Fractures of the Neck, J Bone & Joint Surg 7 575 1925
Koch, S. L.: The Primary Treatment of Wounds, Minnesota Med. 24 747 1941.
Küntscher, G Die Marknagelung von Knochenbrüchen. Tierexperimenteller Teil, Klin. Wchnschr 19 6 1940
Lambotte, A.: Chirurgie Opératoire des Fractures, Paris, 1913 Masson & Cie.
Lapidus, P W Longitudinal Fractures of the Patella, J Bone & Joint Surg 14 351 1932
Leadbetter G W A Treatment for Fracture of the Neck of the Femur J Bone & Joint Surg 15 931 1933.
Leadbetter G W Fractures of the Pelvis, South. M J 25 42, 1932.
Lee, H G Treatment of Fracture of the Clavicle by Internal Nail Fixation; Report of Case, New England J Med. 234 222 1946.
Lee, H. G: Fractures of the Tuberosities of the Tibia, New England J Med. 204 583 1931
Lewin Philip Fractures and Dislocations, New York, 1937 National Medical Book Co., Inc., Vols. I & II.
MacAusland, W R. The Treatment of Fractures of the Olecranon by a Longitudinal Screw or Nail Fixation, Ann. Surg 116 293 1942.
MacAusland, W R. Total Excision of the Patella for Fractures Report of 14 Cases, Am. J Surg 72 510 1946
MacFarlane, M. G The Therapeutic Value [illegible] ngrene Antitoxin, Brit. [illegible] 636, 1943.
McElvenny Robert T Personal Communic[illegible]
McKeever D C Unpublished data.
McKeever F M. Fracture of the Neck of [illegible] Arch. Surg 46
McKeever F M., and Buck, R. M.: Fract[illegible] Process [illegible] Treat[illegible]ment by Excision of Fragment and [illegible]iceps Tendon, J [illegible] 1947
McWhorter G L. Fracture of the Greater [illegible] the Humerus [illegible] Clin. Report [illegible] Operated Cases With [illegible] of Shoulder [illegible] No[illegible] 5 1005 1925
Magnuson [illegible] [illegible]tures, Philadelphia, [illegible] Co.
Mannheimer [illegible] Treatment of Co[illegible] Intern[illegible] 370 [illegible] Nord. med. [illegible]

Marrin M M: Multiple Metatarsal Fractures: The Method of Fixation Mil Surgeon 93: 81, 1943.
Martin L. D., and King A. C.: Preliminary Report of a New Method of Treating Fractures of the Neck of the Femur New Orleans M & S. J 75 710, 1922 23
Michaelis L. S.: Comminuted Fracture-Dislocation of the Shoulder J Bone & Joint Surg 26 303 1944.
Milgram J E.: Tangential Osteochondral Fracture of the Patella, J Bone & Joint Surg 25 271, 1943
Miller, O L., and Baker L. D: Fractures and Fracture Dislocations of the Astragalus, South M. J 32 125 1930
Mitchell, Jos. I Fracture of the Neck of the Femur in Children, J A M A. 107: 1603 1936.
Mixter S J., and Osgood, R. B. Traumatic Lesion of the Atlas and Axis, Ann. Surg 51: 193 1910
Mondor H., and Nardi C. The Metallic Intratibial Prosthesis for Fractures of the Leg Mem. Acad. de Chir 68 326, 1942.
Monteggia, G B. Instituzioni Chirurgiche, ed. 2, Milan, 1813 1815 G Maspero. (From J Bone & Joint Surg 16 354 1934.)
Moore Austin T Fracture of the Hip Joint—A New Method of Treatment, Internat. S. Digest 19 3 3, 1935
— Fracture of the Hip Joint Surg Gynec Obst. 64 420 1937
Moore A. T Blade-Plate Internal Fixation for Intertrochanteric Fractures, J Bone & Joint Surg 26 52, 1944
Morris, H. D Tenon & Mortise Grafts for Bridging Metacarpal Defects Due to Gunshot Wounds Surgery 20 364 1946.
Munro A. H. G., and Irwin, C. G: Interlocked Articular Processes Complicating Fracture-Dislocation of the Spine Brit J Surg 25 621 1938
Murray C. R The Timing of the Fracture-Healing Process. Its Influence on the Choice and Application of Treatment Methods J Bone & Joint Surg 23 598 1941
Murray C. R. The Detailed Operative Technic for Open Reduction and Internal Fixation of Fractures of the Long Bones J Bone & Joint Surg. 26 307 1944.
Murray G: A Method of Fixation for Fracture of the Clavicle, J Bone & Joint Surg. 22 616 1940
Murray, R. C. Fractures of the Head and Neck of the Radius, Brit J Surg 28 106, 1940
Neufeld A. J., Janzen J., and Taylor G M Internal Fixation for Intertrochanteric Fractures, J Bone & Joint Surg 26 707 1944.
Nicolaysen J Lidt om Diagnosen og Behandlingen af Fr colli femoris, Nord. med Ark., Stockholm 8 1 1897
Ober F R Fracture of the Patella. A New Operation, J Bone & Joint Surg. 14 640 1932.
Patrick J Fracture of the Medial Epicondyle with Displacement into the Elbow Joint J Bone & Joint Surg 28 143 1946.
Pauwels, F Der Schenkelhalsbruch ein Mechanisches Problem. Grundlagen d. Heilungsvorganges Prognose und Kausale Therapie. Zeitschrift für Orthopädische Chirurgie Hasenbergsteige Stuttgart, 1935 Ferdinand Enke.
Poyner H. F., and Hucherson, D C: Open Reduction for Fractures of the Pelvic Girdle, Arch. Surg. 55 339 1947
Reich, R. S.: Posterior Dislocation of the First Cervical Vertebra with Fracture of the Odontoid Process, Surgery 3 416 1938.
Rogers, W A. Treatment of Fracture-Dislocation of the Cervical Spine J Bone & Joint Surg 24 245, 1942.
Rogers, W A Cord Injury During Reduction of Thoracic and Lumbar Vertebral-Body Fracture and Dislocation, J Bone & Joint Surg 20 689 1938.
Rose, M. J., Jr., and Sutherland, R.: Fracture Fixation by Transarticular Pin A Technic for Control of Severe Ankle Fractures, Am. J Surg 74 24, 1947
Rowlette, A., Haslem J R., Siegert, R. B., Morris, H. D., and Key J A. Results Obtained by Subcutaneous Pinning of Fractures Through the Neck of the Femur J A M A 107 1010 1936.
Rush, L. V., and Rush, H. L.: A Technic for Longitudinal Pin Fixation of Certain Fractures of the Ulna and of the Femur J Bone & Joint Surg 21 619 1939
Rush, L. V., and Rush, H. L. A Reconstruction Operation for Comminuted Fracture of the Upper Third of the Ulna, Am. J Surg 38 332, 1937
Santos, J V Changes Which the Articular Cartilage of the Hip Joint May Undergo Surg Gynec Obst. 54 630 1932
Schrock, R. D., Johnson, H. S., and Waters, C. H., Jr Fractures and Fracture-Dislocation of the Astragalus (Talus) J Bone & Joint Surg 24 560 1942.
Scudder Charles Locke The Treatment of Fractures, Philadelphia, 1926, W B. Saunders Co.
— The Treatment of Recent Fractures of the Long Bones by Operation Ann Surg. 90 559 1929

Shands, A. R., Luck, J. V., Smith, H. M. A., and Lacoy H. B.: Orthopedic Surgery in the Army Air Force during World War II, (To be published)

Sherman Wm. O'N Vanadium Steel Bone Plates and Screws, Surg Gynec. Obst. 14. 629 1912.

— Operative Treatment of Fractures of the Shaft of the Femur With Maximum Fixation J Bone & Joint Surg 8 494 1926.

—: Operative Treatment of Fractures, Nelson Loose Leaf Living Surgery, New York, 1927 Thos. Nelson & Sons, Vol. III.

Smith, F M Monteggia Fractures; An Analysis of 25 Consecutive Fresh Injuries, Surg. Gynec. Obst. 85 630, 1947

Smith Petersen, M. N: Treatment of Fractures of the Neck of the Femur by Internal Fixation Surg Gynec. Obst. 64: 287, 1937

Smith Petersen, M N., Cave, E. F., and Van Gorder G W: Intracapsular Fractures of the Neck of the Femur Arch. Surg 23 715, 1931

Soeur R.: Intramedullary Pinning of Diaphyseal Fractures, J Bone & Joint Surg 28 309, 1946.

Speed, J S. An Operation for Unreduced Posterior Dislocation of the Elbow South. M. J 18 193 1925

Speed J S., and Boyd, H. B Treatment of Fractures of the Ulna with Dislocation of Head of Radius (Monteggia Fracture), J A. M. A. 115 1900, 1940.

Speed, J S.: Central Fractures of the Neck of the Femur J A. M. A. 104 2060 1935.

Speed, J S., and Boyd, H. B: Fractures About the Elbow Am. J Surg 38 727, 1937

Speed, J S. and Macey H B. Fractures of the Humeral Condyles in Children, J Bone & Joint Surg. 15 903 1933

Speed Kellogg: A Text Book of Fractures and Dislocations, Philadelphia, 1928, Lea & Febiger

Speed, K.: Treatment of Postoperative Infections Following Internal Fixations for Fracture of the Neck of the Femur Surg., Gynec. & Obst. 80 479, 1945.

Steel Bone Plates and Screws, Commercial Standard CS 37 31, U S. Dept. of Commerce Bureau of Standards, Washington, 1932.

Stimson, Barbara B: A Review of the 1933 and 1934 Literature on Fractures, Internat. Abstr Surg. 62 1 1936.

Street, D M., Hansen, H H., and Brewer, B. J The Medullary Nail, Presentation of a New Type and Report of a Case Arch. Surg 55 423, 1947

Stuck, W G The Treatment of Intertrochanteric Fractures of the Femur, Surgery 15 373, 1944.

Taylor A. S. Fracture Dislocation of Cervical Spine, Ann. Surg 90 321 1929

Taylor G M., Neufeld, A. J., and Jansen, J Internal Fixation for Intertrochanteric Fractures, J Bone & Joint Surg 26 707, 1944

Thomas, T T: Fixation by a Wood Screw Without Arthrotomy in Certain Fractures of the Neck of the Femur, Am. J Surg 35 203 1921

Thomson, J E. M.: Comminuted Fractures of the Patella, J Bone & Joint Surg 17 431, 1935.

Thomson, J E. M. Fracture of the Patella Treated by Removal of the Loose Fragments and Plastic Repair of the Tendon Study of 554 Cases, Surg., Gynec. & Obst. 74 860 1942.

Thornton, L., and Sandison C: Fractures of the Knee Am. J Surg 44 178, 1939

Thornton, L., and Sandison, C. Recognition of Modern Treatment of Broken Hips, South. M. J 29 456 1936.

Van Gorder, G W Surgical Approach in Old Posterior Dislocation of the Elbow J Bone & Joint Surg. 14 127 1932.

Van Gorder G W: Surgical Approach in Supracondylar T Fractures of the Humerus Requiring Open Reduction, J Bone & Joint Surg 22 278, 1940

Venable, C. S., and Stuck, W G: The Internal Fixation of Fractures, Springfield, Ill., 1947 Charles C Thomas.

Von Langenbeck Verhandl. d. deutsch. Gesellsch. f Chir., Berlin 7: 40, 1878.

Wainwright, D Fractures of the Olecranon Process, Brit. J Surg 29: 403 1942.

Walton, G L. Further Observations on Cervical Dislocation and Its Reduction, Boston M. & S. J 149 445 1903

Wass, S. H., and Davies, E R.: Excision of the Patella for a Fracture with Remarks on Ossification in Quadriceps Tendon Following Operation, Guy's Hosp. Rep. 91 15 1942.

Watson Jones, R. Dislocations and Fracture-Dislocations of the Pelvis, Brit. J Surg 25 773, 1938

Watson Jones, R. Styloid Process of the Fibula in the Knee Joint With Peroneal Palsy J Bone & Joint Surg 13 258, 1931

— Fractures of the Neck of the Femur Brit J Surg 23 787, 1935-36.

Well R. C Fractures of the Upper End of the Tibia Involving the Knee Joint Minnesota Med 18 180, 1935

Wescott H. Heyward A Method for the Internal Fixation of Transcervical Fractures of the Femur J Bone & Joint Surg 16 3/? 1931
Westerborn, A : Nailing in the Marrow Cavity in Cases of Recent Fracture and Pseudarthrosis. Report of 28 Cases, Acta Chir Scandinav 90 89 1941
Willard DeF P., and Nicholson, J T Dislocation of the First Cervical Vertebra, Ann. Surg 113 464 1941
Wilson, J C. Fractures of the Neck of the Femur in Childhood J Bone & Joint Surg. 22 531, 1940
Wilson I D Treatment of Fractures of the Os Calcis by Arthrodesis of the Subastragalar Joint: A Report on Twenty-Six Cases, J A M A 89 1676 1927
— Fracture of the Lateral Condyle of the Humerus in Childhood J Bone & Joint Surg 18 301, 1936
Wilson Philip D., and Cochrane William A Fractures and Dislocations, Philadelphia, 1925 J B. Lippincott Co.

CHAPTER IX

MALUNITED FRACTURES

Malunited fractures are those wherein union has taken place with the fragments in an abnormal position. The result often is an unsightly deformity of sufficient degree to impair function in one of several ways by blocking of a neighboring joint uneven distribution of weight or incongruity of joint contours with subsequent traumatic arthritis angulation and rotation of the fragments which interfere with proper balance or gait and over riding of the fragments, with material shortening

Malunion is attributable to (1) failure to secure accurate reduction, (2) improper immobilization during the process of healing or (3) negligence in protecting a recent fracture when consolidation is not actually complete. Practically all malunited fractures are preventable by efficient treatment of the fresh fracture. In a small number of cases, however malunion will occur despite the most skillful and thorough treatment

There are certain salient facts regarding malunited fractures with which one must be familiar in order to judge the advisability of operation, or to select the most suitable method of correction. These may be enumerated as follows

1. The roentgenogram frequently demonstrates gross abnormalities of contour which are commensurate with good function. For example, in fractures of the shafts of the long bones, only a fairly good alignment and engagement of the fragments may be followed by a satisfactorily functioning member Further slight internal irregularity although disabling to a minor degree often cannot be improved upon sufficiently to warrant surgery Roentgenograms should be made well above and below the fracture, that the degree of malalignment may be properly evaluated.

2. On the other hand a slight variation from the anatomic contour may be seriously disabling when a fracture involves or is adjacent to a joint.

3 A rotation deformity may not be grossly apparent in the roentgenogram, yet may in itself cause sufficient disability to necessitate operative correction.

4. Gross deformities in young children may be overcome during the process of growth, provided an epiphysis is not involved.

5 The object of operation for malunited fracture is restoration of function although to the patient the cosmetic appearance may be equally important, *surgery is rarely justifiable for cosmetic reasons alone*

6 In some fractures, six months to one year should elapse from the time of the original injury before operative treatment is undertaken. For example, in the presence of severe comminution and displacement of a tarsal bone fusion may take place spontaneously during a period of weight-bearing with the foot supported by a cast or brace permitting painless function.

7 Operation is not indicated until measures have been instituted to combat osteoporosis and atrophy of the soft tissues. If the fracture is in the lower extremity, this may be accomplished by two or three months of weight bearing the extremity being supported by a brace or cast. In the upper extremity, and in the lower extremity if the deformity precludes weight bearing, several months of physical therapy with active motion of the adjacent joints may be necessary before the osseous structure approaches normal

8 Refracture and resetting of the bone is not always feasible. In certain cases, a compensatory procedure may be employed for restoration of function in others, pain may be the predominating symptom, requiring fusion of a joint before complete relief is obtained

SURGICAL TREATMENT OF MALUNITED FRACTURES

PHALANGES OF THE TOES

Malunion of fractures of the phalanges of the foot is rarely accompanied by disability sufficiently severe to warrant operation. If the deformity causes pain, however correction may be easily accomplished through a lateral or dorsal incision which does not injure the tendons. Osteotomy with alignment of the fragments, may be adequate. To insure complete correction however wide resection may be required, this may be carried out with impunity, since skillful movements are not necessary in the toes.

METATARSAL BONES

Fractures of the head or neck of the metatarsal bones may be followed by fixed dorsal contractures of the toes, thus, the operative treatment described for clawtoes is appropriate (Chapter XXII)

In disabling malunited fractures of the shafts, the fragments are practically always angulated toward the plantar surface of the foot, presenting an osseous mass on the sole of the foot. If the fracture is severely comminuted, the mass may simulate a tumor. Operation is not designed to restore perfect apposition and alignment but to correct the angulation so that weight bearing may be possible without undue osseous pressure on the sole of the foot.

Technic.—An incision is made on the dorsal surface of the forefoot parallel with the shaft of the affected bone or bones, often one skin incision will provide access to two bones. The line of fracture is exposed and, with a small osteotome, each bone is refractured. In some cases, a wedge of bone must be removed to permit elevation of the fragments, but under no circumstances should resection be so extensive that nonunion can possibly follow. By pressure from below and forcible flexion of the toes, the fragments may be raised into a slightly overcorrected position. The fragments are fixed in position by an intramedullary pin as described for fresh fractures (p 380)

After Treatment.—A cast is applied from the tibial tubercle to the toes, the bottom of the cast being well molded to maintain the corrected position. Three weeks later the intramedullary pin and the cast are removed, and the foot placed in a plaster walking cast which holds the toes in plantar flexion, a felt pad being inserted beneath the line of fracture. At the end of six weeks the cast is discarded and an orthopedic shoe and an arch support with an anterior pad are fitted



Fig. 370.—A, Malunited fractures of metatarsal bones treated by open reduction and internal fixation with intramedullary bone pegs. B, At nine weeks, union progressing satisfactorily. A year or more is required for reorganization and replacement of preserved bone pegs.

TARSAL BONES

Malunion of the tarsus with the exception of the astragalus and os calcis, may be discussed as a single entity. As fractures of this region are occasioned by violent trauma, several bones may be involved and perhaps severely comminuted, in addition one or more of the tarsal joints may be dislocated. The distal fragment or fragments usually are displaced toward the dorsum of the foot, and in some cases the bones may slightly overlap. In the latter event, the distal fragment produces a prominence on the dorsal aspect, while the proximal fragment lies beneath and forms a mass on the sole of the foot. Occasionally some lateral movements of the foot may be conserved by osteotomy through the site of fracture and reduction of the fragments. As a rule, however even though resection of the articular surfaces is unnecessary lateral movement is lost. Partial or total resection of one or more of the tarsal joints, followed by arthrodesis, is frequently required not only to correct the malposition of the tarsal bones, but to relieve pain and prevent traumatic arthritis from incongruity of the articular surfaces. Since lateral movements are often partially or completely lost, the malunited bones being practically a solid mass, arthrodesis, which obliterates lateral motion entirely does not add materially to the disability particularly in young individuals. Dorsal and plantar flexion are not disturbed. If the subastragalar joint is not involved, only the midtarsal joints need be fused thus conserving motion.

Unless deformity is severe and pain excessive, operative procedures for malunion are not advisable until weight bearing is tried for a period of six months to one year

Technic.—Through an incision lateral to the extensor tendons on the dorsal aspect of the foot (p 137) or through a mid-dorsal incision in line with the third metatarsal bone, the periosteum is reflected exposing the fracture site. In injuries of only a few months' duration the bone is divided with an osteotome at the point of union and if the fragments overlap excessively a small section is removed from each. By means of a bone skid or periosteal elevator the fragments are levered into position. Usually, reduction is stable if desired however holes may be drilled in each fragment and chromic catgut sutures passed through the holes and tied to maintain apposition and stability

When malunion has been present for several months or years, the tarsus may be completely fused and the original site may not be discernible the osteotomy is then carried out through the area of deformity, without regard to the joints or the fracture site. If the deformity is pronounced, reduction cannot be accomplished without wide resection of the bone.

If there is an associated tenosynovitis of the extensor tendons, with dorsal contracture of the toes, the deformity may be corrected subsequently by an operation for clawtoes (Chapter XXII)

After Treatment.—With the foot held at a right angle to the leg a plaster cast is applied from the toes to just below the knee. At the end of one week, a roentgenogram is made through the cast to confirm the position of the bones. Four weeks after operation the cast is removed the foot inspected, and any irregularity corrected. The foot is then placed in a walking cast and weight bearing is permitted with the aid of crutches. Eight weeks postoperatively



Fig. 379.—*A.* Malunited fractures of metatarsal bones treated by open reduction and internal fixation with intramedullary bone pegs. *B.* At nine weeks, union progressing satisfactorily. A year or more is required for reorganization and replacement of preserved bone pegs.

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an orthopedic shoe and steel arch support are fitted and worn for three to six months, or until function is normal. In some cases, swelling and pain may persist for a year and may require the use of a lighter arch support, as the leather cork type (p 28) as well as a leather corset to the foot and ankle.

ASTRAGALUS

Malunion of fractures of this bone always causes serious disability and impairment of function. The neck or body, or both together, may be involved in the malunion, with *consequent incongruity of the ankle, subastragalar*, or astragaloscaphoid joints.

Malunion of the Neck of the Astragalus

Malunited fracture of the neck of the astragalus is analogous to intra capsular or central fractures of the neck of the femur in that circulation is often impaired and some degree of degeneration or sequestration of the head



Fig. 319.—Old comminuted compound fracture of body of astragalus, with excellent result six years after panastragalar arthrodesis.

or body may be present, causing irregularity of the articular surfaces. Union may take place with the distal fragment in rotation, or there may be varying degrees of lateral deviation of the neck with accompanying varus or valgus deformity Since the head is rotated upward and inward, the deformity generally is varus. No attempt is made to correct malunion by osteotomy or refracture of the neck, as nonunion may follow Triple arthrodesis with resection of *suitable wedges of bone is necessary for correction of* the inversion of the heel and the varus deformity of the forefoot (Ch. XXII) If the body of the astragalus is avascular treatment is carried out as described below

Fracture of the base of the neck, or of the anterior portion of the body with upward displacement of the distal fragment, may result in a painful anterior block of the ankle joint. Excision of the protruding portion of bone may restore motion in the ankle, though traumatic arthritis may later develop and necessitate fusion of the ankle.

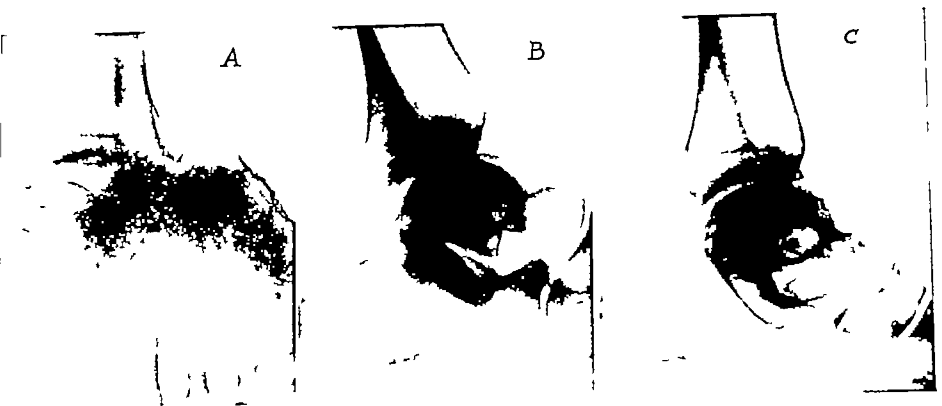


Fig. 381.—A Compound fracture-dislocation of astragalus. B Good result other than pain in subastragalar joint. C Continued conservative treatment followed by spontaneous fusion of subastragalar joint two years after injury with cessation of symptoms.

Malunion of the Body of the Astragalus

Fractures of the body of the astragalus, although exceedingly rare, frequently unite in malposition. Disability is extreme if the fracture involves either the subastragalar or ankle joint, or both

Either arthrodesis or astragalectomy is the proper operative treatment. When the contour of the articular surface of the astragalus is grossly distorted and the bone is viable and not infected, fusion is the procedure of choice. When both the superior and inferior articular surfaces are incongruous, posterior arthrodesis of the ankle (Ch. XV), including the subastragalar joint, is preferable. Panastragalar arthrodesis may be applicable to a few cases of malunited comminuted fractures of the body and neck of the astragalus for this same group with an aviable body calcaneotibial fusion (p 387) is preferable as motion may thus be preserved in the midtarsal joint. Both panastragalar arthrodesis and calcaneotibial fusion are rather difficult and extensive procedures.

In isolated cases, traumatic arthritis may be limited to the ankle joint or to the subastragalar joint In this event, anterior fusion of the ankle (Fig 388) or subastragalar fusion (p 523), respectively is applicable. Good results have been obtained by subastragalar fusion without arthrodesis of the midtarsal joints.

If the original injury was a compound fracture followed by infection and draining sinuses and sequestration of the astragalus, astragalectomy is more suitable. Following removal of the astragalus, a spontaneous fibrous or bony ankylosis between the os calcis and tibia usually takes place. If motion persists *and is accompanied by pain calcaneotibial fusion may be necessary to provide a* painless, stable, weight bearing member The technic of removal of the astragalus is similar to that described for tuberculosis of the astragalus (Chapter XIV)

OS CALCIS

In a large proportion of fractures of the os calcis, even though efficient treatment has been carried out at the time of the original injury pain and disability may persist This is particularly true if the occupation of the individual necessitates his walking over rough ground. As a rule, disability arises from incongruity of the subastragalar joint and consequent traumatic arthritis. Excessive bone formation may be present below and behind the external malleolus. If the lateral deviation or eversion of the os calcis is *pronounced, there is a tendency to valgus deformity and foot strain.*

With a few exceptions, a fair trial of weight bearing aided by arch supports should precede operative treatment (see Fresh Fractures of the Os Calcis, p 389) The surgical procedure consists of resection of a sufficient amount of bone from the subastragalar joint to correct the abnormal weight bearing alignment, followed by arthrodesis. In the presence of an associated traumatic arthritis *of the midtarsal joints, a triple arthrodesis* (subastragalar astragaloscaphoid, and calcaneocuboid) is advisable.

In severe squash fractures, Conn recommends triple arthrodesis as the only means of securing a painless weight bearing foot in both fresh and mal united fractures, having found that there is not only a derangement of the subastragalar joint but also a subluxation of the calcaneocuboid and astragalo-

scaphoid joints subsequent to depression and fracture of the sustentaculum tali According to Conn, subastragalar fusion is illogical in that the head and neck of the astragalus is left projecting forward without support, and a constant weight bearing lever is thus produced, which tends to prevent fusion He contends that since the astragaloscaphoid calcaneocuboid and subastragalar joints have a reciprocal action, triple arthrodesis is preferable to subastragalar fusion Moreover, triple arthrodesis does not add to the disability in that the majority of motion is lost following the original injury

Our studies would indicate that, unless the midtarsal joints are involved at the time of the fracture, arthrodesis should be limited to the subastragalar joint. The slight amount of motion in the midtarsal joints increases with activity and is definitely beneficial

Subastragalar Arthrodesis

Technic.—A short Kocher U incision, beginning above and posterior to the external malleolus and extending below the malleolus onto the antero lateral surface of the foot gives an excellent exposure of the subastragalar joint. The peroneal tendons are displaced from behind the external malleolus and retracted forward Excess bone on the lateral surface of the os calcis

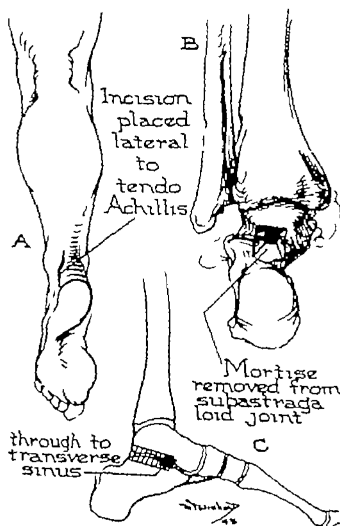


Fig. 212.—Gallie subastragalar fusion for malunited fracture of os calcis. *A* Line of skin incision. *B C*, Mortise removed from subastragalar joint, extending from posterior surface to transverse sinus (From Gallie, W E. J Bone & Joint Surg. 25: 731 1943)

is removed with an osteotome. Also by means of an osteotome the surfaces of the subastragalar joint are resected, the larger portion being removed from the medial side of the joint to correct the lateral deviation or eversion of the os calcis after all raw osseous surfaces are approximated. The peroneal tendons are replaced in their sheaths and the latter are sutured.

If the midtarsal joints (calcaneocuboid and astragaloscaphoid) are involved, fusion is accomplished as described for triple arthrodesis.

After Treatment.—(See p. 519.)

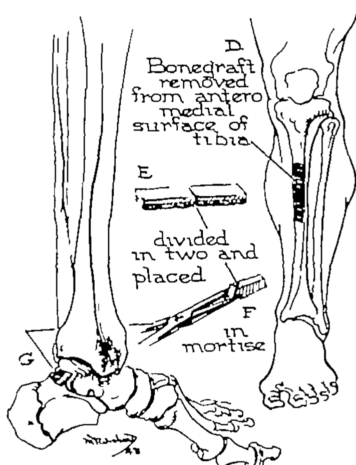


Fig. 333.—Tibial grafts inserted to fill mortise. (From Gallie, W. E.: J. Bone & Joint Surg. 25: 731, 1943.)

In the belief that fusion of the subastragalar joint should be accomplished by some more simple method than those usually employed, Gallie has advised an arthrodesis of the subastragalar joint from the posterior aspect. Although this procedure is relatively simple it does not incorporate any means of correcting the relationship of the astragalus to the os calcis, or any other deformity of the foot. Gallie contends that, ordinarily the mild valgus position of the heal may be disregarded. The procedure is not suitable if the primary deformity is a varus relation of the os calcis to the astragalus, as excessive weight would thus be placed upon the head of the fifth metatarsal leading to a painful callous.

Technic (Gallie).—With the patient in a prone position a longitudinal incision is made along the lateral border of the tendo achillis for two and one-half to three inches (p. 139). The posterior capsule and synovial membrane of the ankle and subastragalar joints are then incised transversely. The subastragalar

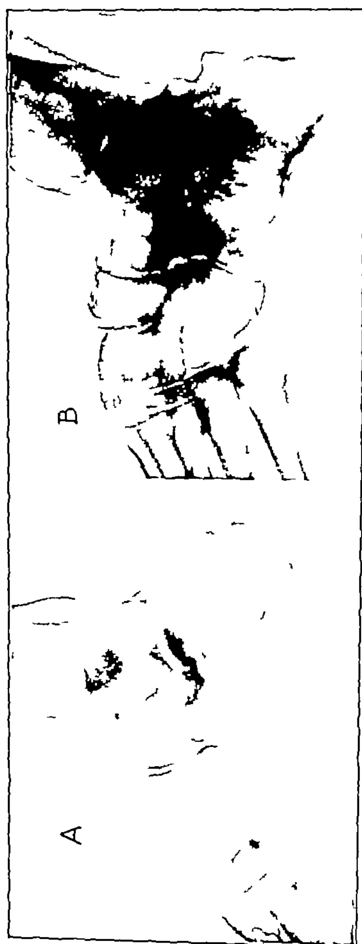


Fig. [illegible].—A Old fracture of os calcis with fairly satisfactory reduction, though incongruity of substragalar surface. B Pain relieved by substragalar arthrodesis.

joint is located by medial and lateral motion of the os calcis. The substragalar joint is probed, that one may be certain of its general direction, a mortise is then cut in the os calcis and astragalus, approximately one-half inch wide, one fourth inch deep and as far forward as the transverse sinus of the foot. With the knee flexed a tibial graft, two and one-half inches long and one-half inch wide is removed from the anteromedial aspect of the upper portion of the tibia. *This graft is divided into two portions, and one end of each graft is beveled.* Cancellous bone is next packed into the depth of the mortise. The two bone grafts are then driven into the mortise, their cortical surfaces being apposed If the grafts are of proper dimensions, their cancellous surfaces will press snugly against the lateral walls of the mortise.

After Treatment.—See page 519

MALUNITED FRACTURES ABOUT THE ANKLE

In rare cases, malunion may follow the most accurate reduction of any of the following fractures of the lower end of the tibia and fibula fractures of the fibula and of the internal malleolus (Pott s fracture) or bimalleolar fracture fracture of the fibula with rupture of the deltoid ligament, inversion or reversed Pott's fracture diastasis of the tibia and fibula from rupture of the interosseous ligament, with or without Pott s fracture fracture of the internal and external malleoli, associated with fracture of the posterior portion of the articular surface, or trimalleolar (Cotton's) fracture, explosion fracture of the ankle

The disability from malunited fractures of the ankle is usually so extreme that only surgical measures will afford relief Varus or valgus of the joint even though of minor degree produces a faulty weight-bearing line and, eventually traumatic arthritis This faulty alignment cannot be counteracted in the knee, which is a hinge joint

Any defect in the articular surface of a joint predisposes roughening of the joint and traumatic arthritis. These changes tend to increase with time and use especially in closely fitting weight bearing articulations. The pathologic process is more severe at the ankle joint because of the close fit of the astragalus and the ankle mortise, further, although the ankle sustains more weight than the knee its actual weight bearing surface is smaller All of these factors contribute to a poor prognosis in any disturbance of the articular surface or abnormality of the weight bearing line of the ankle

The operation should be chosen according to the age and occupation of the patient and the degree and duration of malunion. Reconstructive procedures for malunited fractures of the ankle are usually undertaken to restore the normal weight bearing alignment of the joint or to combat symptoms secondary to traumatic arthritis. Frequently these two principles are combined. When correction of deformity is the chief consideration, some type of osteotomy is usually sufficient. In the presence of a definite traumatic arthritis, arthrodesis of the joint is generally indicated.

On the whole the results of conservative operations for correction of recent deformity incident to malunited fractures of the ankle have been satisfactory If a malposition of the astragalus in relation to the ankle mortise

has been present for three months or longer, pathologic changes usually have developed in the articular cartilage to a degree which precludes a painless and functional range of motion For this reason even after anatomic reconstruction of the joint surfaces, osteotomy is generally followed by poor function If the deformity is of short duration, and the anatomic relationship can be restored with minimal trauma to the articular surfaces good function is the rule provided the reconstruction operation fulfills the following requirements restoration of proper weight bearing alignment of the leg as a whole, restoration of anatomic relationships between the articular surfaces of the tibia fibula and astragalus restoration of a satisfactory range of painless motion in the ankle

If advanced arthritic changes have developed from roughening of the articular surfaces, restoration of the normal weight bearing line of the ankle, and replacement of the astragalus in its anatomic relationship to the ankle mortise is not sufficient Pain and swelling will persist on weight bearing and motion will be limited A strong stable painless ankle without motion is preferable to a weak painful joint with limited motion

A slight limp usually follows fusion of the ankle In young individuals the limp is lessened by compensatory motion in the midtarsal joint If the ankle is arthrodesed in a position of equinus, the limp tends to be more severe as the patient has difficulty in completing the terminal phase of the step from inability to dorsiflex the ankle Difficulty also may be experienced in walking over rough ground especially following the posterior technic, wherein motion of the subastragalar joint is also obliterated. This disadvantage is not a factor after anterior fusion

In 1935 Speed and Boyd studied fifty cases of malunited fractures of the ankle in only eight of these was fusion performed The result was poor in a number of the remainder following more conservative surgery, and it was concluded that arthrodesis would have provided a better result Since that study forty additional malunited fractures of the ankle have been treated by the clinic staff an arthrodesis having been carried out in twenty five These data indicate, in general our change in policy Approximately 82 per cent of the patients with fusion obtained a satisfactory weight bearing number the most common cause of failure being lack of fusion following the operation with subsequent pain swelling and limp

The operative procedures for these fractures may be enumerated as follows (1) refracture, (2) *supramalleolar osteotomy* (3) correction of diastasis of the tibia and fibula with or without refracture, (4) arthrodesis with or without supramalleolar osteotomy or refracture Every type of malunion cannot be included though the measures subsequently described may be altered according to the demands of the individual case.

Refracture of Bimalleolar, or Pott s, Fracture

Refracture of a typical Pott s or eversion type of fracture is indicated in the presence of faulty weight bearing alignment with only slight if any persistent traumatic arthritis. The procedure is more suitable for young adults with mild deformity In elderly individuals, conservative measures, such as a brace may suffice.

When only the external malleolus has been fractured and the deltoid ligament partially or completely ruptured osteotomy of the fibula as described below may correct the valgus deformity Excision of scar tissue from the space between the internal malleolus and astragalus may be necessary before these bones can be properly approximated

In bimalleolar fractures, osteotomy of both malleoli usually is required.

Technic.—A two-inch longitudinal incision is made over the line of the fibular fracture, which generally is three inches above the external malleolus. In order to elongate the bone, yet provide ends sufficiently square to permit engagement, the fibula is refractured by a Z-shaped or oblique osteotomy If the fragments are overlapped union may be broken up and the ends of the fragments freshened and engaged

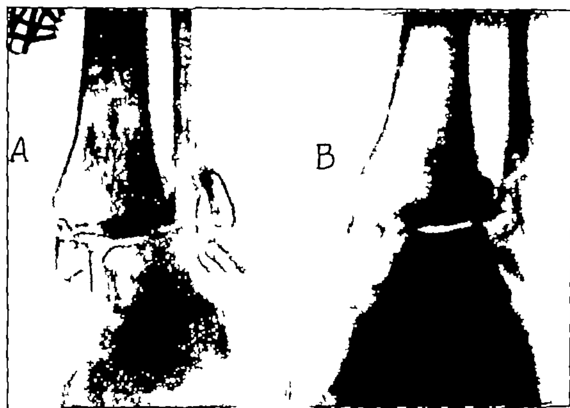


Fig. 186.—*A*, Malunited Pott's eversion fracture. *B* Restoration of weight bearing alignment following bimalleolar osteotomy In these cases, correction is facilitated by complete mobilization of external malleolus.

If the internal malleolus is united in malposition, a second longitudinal incision one inch in length is made just above the base of the internal malleolus. A small osteotome is inserted down to the bone and driven with a mallet from above downward and outward through four fifths the diameter of the malleolus. This osteotomy is carried out preferably through the medial portion of the tibia just above the old fracture line, as a broader osseous surface may thus be obtained. The internal malleolus is then manually refractured by forcible adduction of the foot Engagement of the fibular fragments will be of material mechanical value in maintaining the corrected position. If the astragalus is not approximated to the internal malleolus, the ankle joint is fully exposed and the intervening scar tissue removed. The internal malleolus is usually fixed in position by a screw

When there is an associated equinus deformity, in addition to the bimalleolar osteotomy, the tendo achillis must be lengthened by a plastic operation (Ch XVI) through a third and posterior incision

After Treatment.—As the cast is applied with the foot in the corrected position, pressure is exerted to approximate the astragalus to the internal malleolus. The foot should be at a right angle to the leg or in slight equinus and slight inversion, rarely extreme inversion is required Roentgenograms should be made through the cast immediately to confirm the reduction. In the anteroposterior roentgenogram the joint line of the ankle must be in a transverse plane and at a right angle to the long axis of the tibia, further, the internal articular surface of the astragalus must closely approximate the external articular surface of the internal malleolus, and the external malleolus must extend one half inch below the internal malleolus. The lateral view must show a normal relationship between the astragalus and the tibia. Should there be any divergence from these positions the cast should be removed and proper alignment again attempted Further roentgenograms should be made at the end of one week and three weeks to insure continued alignment. Six weeks following operation the cast is removed the foot restored as nearly to the neutral position as the degree of osseous union will allow, and placed in a walking boot cast An ankle brace with an inner T strap and arch support is fitted ten to twelve weeks postoperatively and worn for three to six months. Physical therapy will materially shorten convalescence.

This operation should be successful in properly selected cases. If pain and disability persist from traumatic arthritis which was not apparent in the roentgenogram prior to operation or if arthritis develops secondary to operative trauma, fusion of the ankle joint is always possible.

Supramalleolar Osteotomy for Pott's Eversion Fracture

Following union of a Pott's fracture with a valgus deformity but with normal relations between the articular surfaces of the tibia and astragalus, a supramalleolar osteotomy is the procedure of choice. This osteotomy is well above the joint line at the position which appears best suited to correction of the valgus deformity and which permits restoration of the normal weight bearing alignment of the foot and ankle with facility and without extensive dissection of the soft structures or invasion of the ankle joint proper The method is ideal when, instead of the usual fracture of the internal malleolus, the line of fracture extends across the entire lower end of the tibia just above the joint surface in these cases, the relationship between the articular surfaces of the ankle joint remains practically normal.

Supramalleolar osteotomy is not suitable, however if the anatomic relation between the astragalus and tibia has been disturbed. *Mere restoration of the general weight-bearing alignment of the leg is not sufficient, as the altered joint line of the ankle must always be restored to normal.*

The procedure may be carried out through one or two incisions.

Technic.—A longitudinal incision is begun at the level of the joint line and extended upward over the fibula a distance of three inches. To elongate the fibula and engage the ends of the fragments, the bone is refractured by a Z-shaped or oblique osteotomy Through the same incision, the lateral surface of the tibia is then exposed one half inch above the joint line, and an osteotome three-fourths inch in width is driven transversely through the bone.

The inner aspect of the leg is placed on a wedge shaped and padded block of wood which has been placed in a sterile pillow case and the foot with the lower fragment is angulated medially to correct the valgus deformity The fragments of the fibula are then engaged and interlocked this gives excellent internal fixation and prevents recurrence of the deformity If desired a small wedge graft from the shaft of the tibia may be inserted into the lateral aspect of the osteotomy site as described for inversion fractures

After Treatment.—(See p 529)

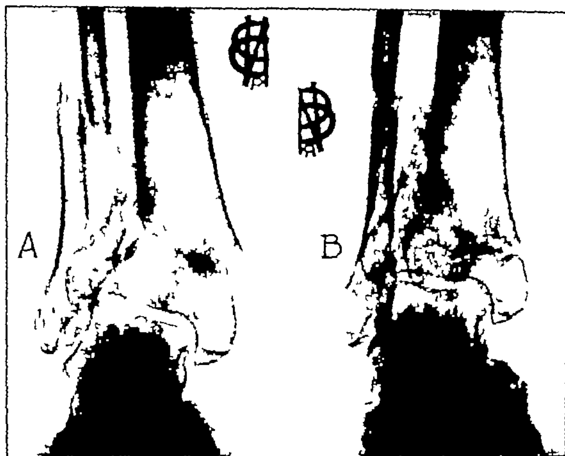


Fig. 356.—A Eversion type of Pott's fracture, in which tibial fragment includes entire lower end of tibia. Union in valgus position relation of joint surfaces undisturbed. Ideal type for supramalleolar osteotomy B Excellent anatomic and functional result following reconstruction by supramalleolar osteotomy Reduction of fragments of fibula particularly important in maintaining proper relationships.

Supramalleolar Osteotomy for Pott's Inversion Fracture

In fractures of the external malleolus associated with fracture of the entire lower end of the tibia just above the joint surface and consequent varus deformity, or in those rare cases of varus deformity following a Pott's fracture, the reverse of the foregoing technic is employed

Technic.—The soft tissues over the lower end of the fibula are incised longitudinally a distance of one inch, and an osteotomy is carried out obliquely through the site of the fracture

A two-inch longitudinal incision is then made over the medial aspect of the tibia beginning just above the joint line and extending upward. A three fourths inch osteotome is driven transversely through the tibia one inch above

the joint surface the outer aspect of the leg is placed on a wedge shaped block, and the foot and distal fragments are angulated laterally to correct the varus deformity

The triangular space created at the site of the osteotomy in the tibia is filled by a cortical graft three eighths to one half inch in diameter set on edge, and with small bone chips. The graft and bone chips are obtained from the upper third of the shaft of the tibia through a separate incision

After Treatment.—The foot is immobilized in the neutral position The treatment thereafter is similar to that described previously (p 529)

Correction of Diastasis of the Tibia and Fibula With or Without Refracture

This is an extensive operation and should be undertaken only in young individuals when the displacement is of long duration and refracture of the internal malleolus and fibula is involved a fusion operation is preferable

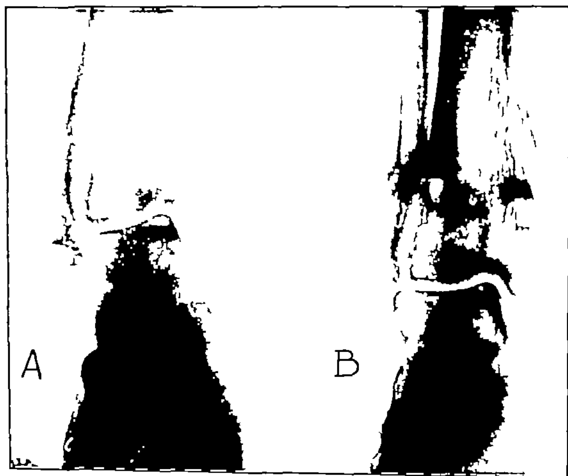


Fig. 387.—*A* Pott s inversion fracture. *B* Treated by supramalleolar osteotomy and wedge graft.

Technic.—An anterolateral incision, beginning two inches above the joint line and just medial to the fibula is carried to the level of the head of the astragalus. The extensor tendons are retracted medially and the interosseous ligament exposed all scar tissue which has formed as a result of rupture of this ligament is completely excised In order to appose the medial surface of the body of the astragalus and the internal malleolus, scar tissue is likewise removed from this area. The articulation between the external malleolus

and the lateral border of the astragalus usually is normal, as the astragalus follows the fibula. After these obstacles have been removed the tibia and fibula may be brought into normal relations by pressure from the lateral aspect. Should a fracture of the fibula or of the internal malleolus prevent approximation, refracture, as described for Pott's fracture may be required.

Reduction, when accomplished, cannot be maintained without some form of *internal fixation (Fig 261)* *The lateral edge of the incision is therefore re* tracted outward and posteriorly, exposing the lower extremity of the fibula, and, with a $\frac{7}{64}$ or $\frac{1}{8}$ inch drill, a hole is made through the shaft of the bone, and thence through both cortices of the tibia. Since the fibula lies slightly posterior to the midline of the tibia in the region of the tibiofibular joint, the hole must be angulated anteriorly The tibiofibular joint is stabilized by the insertion of a screw of appropriate length. As the screw is tightened, the ankle should be maintained in *90 degrees dorsiflexion. Following completion of this procedure,* the astragalus should move smoothly and freely in the ankle mortise

After Treatment.—(See p 529)

Refracture of Trimalleolar (Cotton's) Fracture

Malunion occurs more often in trimalleolar or Cotton's fracture, than in bimalleolar or Pott's fracture This is explained by the fact that the entire posterior *one-third or one half of the articular surface* of the tibia may be displaced Since the fragment is firmly attached by ligaments to the astragalus and external malleolus, the three move together posteriorly and superiorly as well as laterally

If malunion of the trimalleolar fracture is discovered within the first four weeks, manual reduction may be attempted, should this fail, the fragments may be replaced by a technic similar to that described for open reduction of fresh Cotton's fractures. When malunion has definitely taken place, however reconstruction operations designed to preserve motion in the ankle are always *exceedingly difficult, and frequently impossible. The difficulty depends upon* three factors (1) the size of the posterior fragments, (2) the extent of scar tissue formation, and (3) the degree of osteoporosis of the bone. When the posterior fragment is small and there is practically no posterior displacement of the astragalus, the operative principles described for the treatment of Pott's fracture may be followed

In *typical trimalleolar* or Cotton's *fracture* with malunion of long duration, satisfactory reduction usually is impossible when the posterior fragment includes one-third to one-half the articular surface of the tibia and this fragment and the astragalus are displaced posteriorly Correction of the *valgus deformity and external rotation is no more difficult* than in the usual Pott's fracture the real problem is encountered in freeing the displaced posterior fragment and bringing the astragalus forward to its normal position beneath the articular surface of the tibia. The organization of scar tissue and the contracture *of the posterior capsule and tendo achillis hold the astragalus* firmly in the position of posterior and upward displacement. Even though the soft tissues and ligaments about the ankle joint are extensively dissected the usual osteotomies of the malleoli are carried out, and the tendo achillis lengthened, strenuous manual force is necessary *to push the astragalus forward*

The combined dissection and force generally is damaging to the already degenerated joint surfaces and leads to traumatic arthritis and impairment of function Under these circumstances, fusion of the ankle joint is usually preferable to an attempt to preserve ankle motion

Arthrodesis for Malunited Fracture of the Ankle

Arthrodesis is indicated as a primary procedure in the following types of cases

1 Pott's fractures with or without deformity, in which the roentgenogram demonstrates definite arthritic changes with roughening or distortion of the joint surface, accompanied by persistent pain and disability

2. Malunited trimalleolar or Cotton's fractures of long duration with posterior and upward dislocation of the astragalus.

3 Cases wherein during the course of attempted conservative reconstruction, the deformity cannot be completely corrected or such extensive surgery or excessive manipulative force is required that subsequent arthritic changes in the ankle will be inevitable

4 When the patient is financially unable to take the risk of a reconstruction operation which though correcting deformity and permitting motion, involves the possibility and even probability that pain and disability will persist.

Technic.—(See p 534 Chapter XV)

At the time of operation for fusion, pronounced malalignment, if present, should always be corrected by refracture or supramalleolar osteotomy, otherwise consequent foot strain may be severely disabling This additional procedure does not materially complicate the operation nor prolong the period of recovery

Correction of Deformities From Injury of the Lower Tibial Epiphysis

Separation of the lower tibial epiphysis may lead to some disturbance of growth even though anatomic apposition is obtained. As time passes, the entire epiphysis may cease growing while the fibular epiphysis continues to grow producing a varus deformity Or the epiphysis may be so injured that growth will cease on one side, forming a joint line which is at an angle to the normal weight bearing alignment Surgical interference is postponed as long as possible otherwise the following procedures may have to be repeated from subsequent recurrence of the deformity in younger children two to three operations may be necessary before full growth is attained. The stapling procedure described by Blount (Ch. XXII) may provide a satisfactory solution to this problem

For valgus deformity due to cessation of growth of the lateral side of the lower tibial epiphysis, supramalleolar osteotomy one inch proximal to the epiphysis is carried out, as described for a typical malunited Pott's fracture (p 529) When growth of the medial side of the epiphysis is arrested the oblique line of the ankle joint and varus deformity are corrected by supramalleolar osteotomy as described for Pott's inversion fracture (p 530) If growth of the entire lower tibial epiphysis is arrested and the fibula continues to grow blockage of the lower fibular epiphysis may be necessary

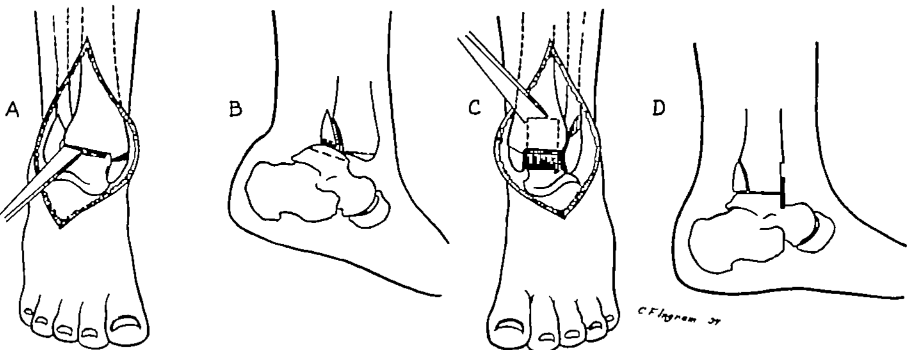


Fig. 388.—Anterior fusion fo malunited fractures of ankle. *A* and *B* Exposure through anteromedial incision. Sufficient amount of articular surface removed to allow restoration of astragalus to proper weight bearing position beneath tibia. *C* and *D* Sliding graft removed from lower end of tibia, placed across joint, and countersunk into niche in astragalus.

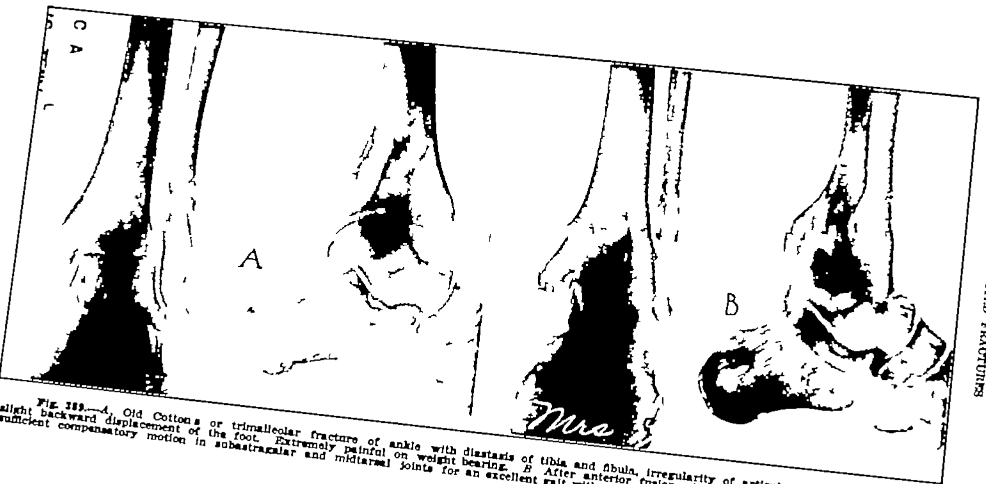


Fig. 389.—*A*, Old Cotton's or trimalleolar fracture of ankle with diastasis of tibia and fibula, irregularity of articular surface of tibia, and slight backward displacement of the foot. Extremely painful on weight bearing. *B*, After anterior fusion of ankle joint. Patient has developed sufficient compensatory motion in subastragalar and midtarsal joints for an excellent gait without pain.

The younger the child the greater is the likelihood of excessive shortening at maturity At an appropriate age discrepancies in length of the lower extremities may be corrected by blocking the lower femoral or upper tibial epiphysis of the normal extremity (Chapter XXII)

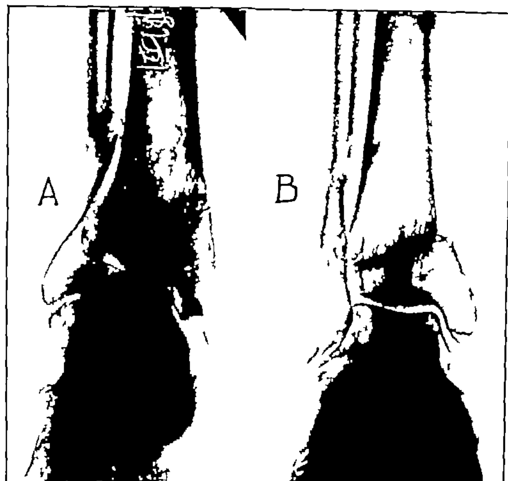


Fig. 390 —*A* Old injury of lower tibial epiphysis with fracture of fibula. Valgus position. *B*, Excellent restoration of weight bearing alignment following supramalleolar osteotomy and reduction of fragments of fibula.

SHAFTS OF THE TIBIA AND FIBULA

Disability arises largely from rotation and lateral and posterior bowing Often there is an associated equinus deformity of the foot from contracture of the tendo achillis. The length of the extremity is rarely decreased more than one inch in oblique or spiral fractures this amount of shortening is not sufficient to warrant refracture provided the fragments are in satisfactory alignment. The angulation usually may be corrected by simple osteotomy Before operation, the nature and contour of the malunited fracture is examined and the line of osteotomy determined to insure the most perfect correction.

At best, satisfactory alignment is difficult to maintain. Some means of internal fixation such as a metallic plate, or preferably an onlay bone graft, should be employed the latter is particularly applicable to fractures of the middle and lower third of the tibia wherein nonunion or slow union is common.

Technic.—A longitudinal incision one inch in length is made over the crest of the bow on the inner or anterior aspect of the tibia and carried through the

periosteum A three-fourths inch osteotome is inserted to the bone, then turned to a right angle with the shaft, or to the proper angle for severance of the bone, and driven with a mallet through three-fourths of the shaft The remainder of the shaft is refractured by manual force. The fibula may now be easily fractured in a similar manner The fragments of the tibia are next angulated and rotated into proper relationship Even at the expense of shortening the ends of the fragment should be dressed so as to provide a maximum degree of contact Prior to the application of internal fixation, the ends of the fragments should be impacted and this status maintained until fixation is secured Minimum contact at the osteotomy site incident to defects from comminution or absorption is an indication for a bone-graft procedure in preference to metallic fixation, regardless of the location of the fracture in the shaft.

After Treatment.—Postoperative care is similar to that employed following open reduction of fresh fractures, although a more prolonged period of immobilization and support may be necessary

CONDYLES OF THE TIBIA

A change in the relation of the weight bearing surface following fractures of the condyles of the tibia, with moderate or severe displacement, gives rise to an increase of the articular space, with relaxation of the ligaments of the knee on the affected side, and a valgus or varus weight bearing alignment, frequently with some degree of rotation If malalignment is of a material degree and is not corrected traumatic arthritis with extreme disability will follow

The procedure of choice varies according to the type of fracture and the exact source of the associated disability Preoperatively, the degree of lateral stability would apparently indicate a ligamentous repair, after correction of the bony deformity however the joint is usually stable

Since the disability of malunion may arise chiefly from axial malalignment, disturbance of the weight-bearing surfaces of the tibia is often unnecessary A transverse subcondylar osteotomy combined with the insertion of a graft is employed. This is particularly appropriate if the patient is middle aged, the malunion of long standing and the lateral displacement not pronounced In other cases, an oblique osteotomy in line with the fracture is necessary The depressed condyle is elevated and fixed in place by screws, the defect being filled by bone grafts This procedure is applicable to young individuals with a relatively recent fracture

In some cases deformity of the condyle and degeneration of the articular cartilage are so severe that reconstruction is impractical. If the bone is of sufficiently good quality the contour of the bony surface is satisfactory, and the other prerequisites can be met, an arthroplasty may be performed. Otherwise arthrodesis will provide a painless, stable knee

Subcondylar Osteotomy and Wedge Graft.—An incision is made over the anterolateral aspect of the knee, beginning one inch above the joint, and extending distally parallel with the shaft for three inches By an inverted L-shaped incision along the lateral condyle and crest of the tibia, the origin of the extensor muscles is detached, and the muscles are dissected from the bone subperiosteally The bone is completely severed by transverse osteotomy at a point immediately distal to the tibial tubercle. A broad osteotome being used as a lever the entire upper fragment is tilted upward and the shaft angulated medially thus largely

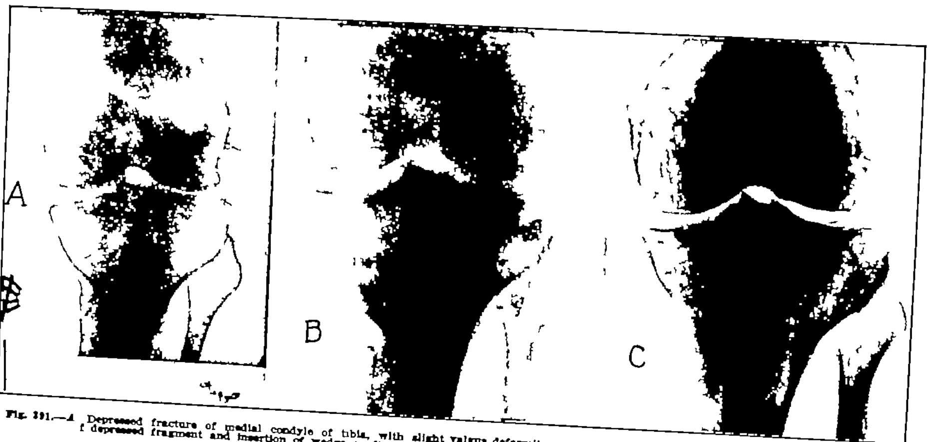


Fig. 391.—*A* Depressed fracture of medial condyle of tibia, with slight valgus deformity and instability of the knee. *B* Immediately after elevation of depressed fragment and insertion of wedge graft. *C* Seven years postoperatively patient has excellent functional result.

restoring the normal transverse plane of the tibial condyle and a normal alignment of the extremity as a whole Elevation of only the depressed fragment produces a refracture through the articular surface this fragment may be difficult to hold in its proper articular relationship Further attempts to pry the segment into position usually lead only to crushing of the fragment, rather than to correction of the deformity The wedge-shaped or cuneiform space at the site of the osteotomy is filled with bone grafts.

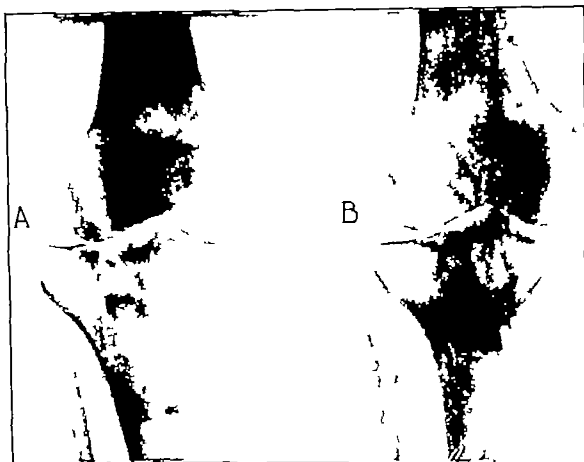


Fig 392—*A*, Old displaced and rotated fracture of medial condyle of tibia, with lateral displacement of tibia on femur Varus deformity of knee and extreme instability *B* No attempt made to restore proper relationship of articular surfaces treated by transverse subcondylar osteotomy and insertion of wedge grafts. Excellent weight bearing alignment restored.

Through an anterior incision three inches in length and two inches below the first incision the shaft of the tibia is exposed and a free cortical transplant of the proper dimensions to serve as a wedge (usually three-fourths inch in width and approximately one and one half inches in length) is removed with the endosteum intact The graft is set on edge and by means of an inlay, is driven tightly into the space beneath the condyle. Cancellous bone from the opening in the tibia, together with a few shavings from the surface of the tibia, is inserted about the graft. There should be no undue lateral motion after operation. Corticocancellous grafts consisting of the full thickness of the ilium provide more stability at the osteotomy site though removal of the grafts add slightly to the magnitude and length of the procedure Prior to closure, roentgenograms should be made to demonstrate whether the normal plane of the joint surfaces has been restored

A similar type of procedure may be used for malunited fractures of the medial condyle.

After Treatment.—The knee is held in extension and immobilized in a cast which extends from the toes to the groin. At the end of four weeks, a second roentgenogram is made although the cast is not removed unless there is considerable space between the cast and limb In the latter event, a second snugly fitting cast is applied Union should be perfectly solid after eight weeks no direct weight bearing should be allowed, however as the depression may easily recur A Thomas caliper brace is therefore applied, with a drop ring catch at the knee to permit motion on sitting Active and passive motion and physical therapy are instituted and walking is permitted with crutches, practically all the weight being borne by the crutches and the Thomas ring



Fig 391.—*A* Old comminuted, inverted Y fracture of condyles of tibia. *B*, Satisfactory weight-bearing alignment restored by osteotomy below the condyles and insertion of tibial wedge graft.

At the end of one month the patient is allowed to resume weight-bearing gradually and after an additional four weeks, or the sixteenth week following operation, to discard the crutches. Five months postoperatively the brace also may be discarded or if advisable, the Thomas ring may be removed and full motion permitted at the knee while the brace is retained for another month. During this time active movements are gradually increased to develop the musculature of the thigh and leg In comparatively young or robust individuals, the roentgenogram and clinical examination may demonstrate a more rapid consolidation, and the after treatment may be adjusted accordingly In some cases the brace may be removed at the end of four months. One should



Fig. 394.—*A* Malunited fracture of external condyle of tibia eighteen months after treatment of injury elsewhere, by conservative measures. Patient had a fairly stable knee with minimum pain. *B* Reinjury of the knee exacerbated arthritic changes. Eight years after original injury disability is severe. *C* Eight months after arthrodesis valgus position has been corrected, union is solid and weight bearing is painless.

bear in mind the possibility of recurrence of the depression however and prevent weight-bearing and undue strain until fusion of the grafted area is solid.

The results of this operation are most satisfactory function being materially improved, and lateral instability being as a rule, corrected.

Refracture and Internal Fixation.—The operative field is exposed as described above, although the incision must extend proximally for a sufficient distance to expose the knee joint. The external semilunar cartilage is examined and, if fractured or displaced, the anterior two-thirds or the entire cartilage is excised. All scar tissue is dissected from between the tibia and the condylar fragment, and their surfaces are denuded. The fragment is next refractured at its base, the osteotome being passed from without in an upward and medial direction The soft tissue attachments should be severed only at the line of fracture or as necessary to mobilize the fragment. A Knowles pin is drilled into the fragment and used as a lever to accomplish reduction Another pin of appropriate size is next drilled into the fragment, across the fracture site and into the opposite tibial condyle The first Knowles pin is then drilled across the fracture site to maintain efficient fixation. Any residual defects are eradicated with cancellous bone Since there is some loss of bone substance in this type of fracture, perfect apposition and contour cannot be restored

After Treatment.—With the knee extended, a plaster cast is applied from the toes to the groin After four weeks the cast is removed the extremity is placed in a modified Thomas hinge splint and exercises are instituted by the patient with the aid of overhead pulleys. At this time, also walking is permitted with crutches, the limb being supported by a Thomas caliper brace. If consolidation of the bone is adequate at twelve weeks postoperatively the crutches may be discarded The Thomas ring is removed at the end of the sixteenth week and walking with free motion in the knee is allowed.

Inverted Y Fractures of the Condyles of the Tibia

Malunited fractures of both condyles, or malunited Y fractures, are approached on both sides and corrected by the method described for malunion as described above Fixation may be secured either by Knowles pins, or by a Webb bolt, according to the technic followed in fresh Y fractures of the condyles. The operation is extensive and usually should be employed only as a preliminary measure, to restore contour for a future arthroplasty Rarely can a practical degree of function be expected unless correction is made within a few months after injury even then, osteoporosis may make replacement of the fragments difficult. In an elderly individual, fusion of the knee is far more satisfactory In selected cases subcondylar osteotomy (p 537) with restoration of weight-bearing alignment may be sufficient.

DEFORMITIES FROM INJURY OF THE UPPER TIBIAL EPIPHYSIS

Deformities secondary to traumatic injuries of the upper tibial epiphysis are less common than those of the ankle or lower femoral epiphysis.

Correction of Genu Recurvatum

Genu recurvatum from an anterior tilt of the tibial plateau or depression of the entire anterior half of the articular surface of the tibia is seldom primarily induced by trauma. Usually the deformity follows operative inter

ference with the anterior half of the upper tibial epiphysis during removal of a graft. The posterior half of the epiphysis continues to grow, while the anterior half is fused, producing an anterior tilt to the tibial plateau which is demonstrable in the roentgenogram. Clinically a genu recurvatum of some degree develops as abnormal growth ensues. We have observed three cases wherein this occurred. In one case, that of a boy thirteen years of age, the anterior tilt followed removal of a graft from the upper portion of the tibia. Although the graft was well below the epiphyseal line, the epiphysis was apparently injured when a curette was employed to remove cancellous bone from the condyles of the tibia. In the second case, the deformity followed an operative arrest of epiphyseal growth wherein only the anterior half of the epiphysis was blocked. In another case the deformity was apparently the result of a fracture involving the epiphysis. More commonly, this deformity is secondary to poliomyelitis.

Brett, in 1935, independently described a technic for correction of genu recurvatum caused by anterior tilting of the articular surface of the tibia. His technic was similar to that described by Lexer in 1931.

Technic (Brett).—A transverse curved skin incision is begun just above the inner condyle of the tibia, crossed over the patellar tendon just above the tibial tuberosity, and terminated on the outer condyle. The flap of skin is dissected upward and an incision is made on each side of the patellar tendon to allow exposure of the tibia immediately behind the tendon. (Sutherland and Rowe have used an approach which provides excellent exposure for anteroposterior osteotomies through the metaphyseal region of the upper end of the tibia. The incision begins in the midline over the knee and extends beyond the tibial tubercle. The patellar tendon is then reflected from the tibial tubercle together with a substantial V section of bone. The V cut is extended proximally through the capsule of the knee joint on each side of the patellar tendon and patella. By turning this flap proximally the entire anterior surface of the tibia is exposed for osteotomy. After the operation is complete, the tibial tubercle is replaced, and fixed by metal nails or screws.) With a thin osteotome an osteotomy of the tibia is carried out just below the attachment of the capsule, the cortex being left intact posteriorly. The anterior surface of the tibia is then elevated, the posterior cortical surface acting as a hinge. A sufficient number of bone chips are placed in the gap to maintain the corrected position.

After Treatment.—A cast is applied from the groin to the toes, maintaining the knee in extension. Physical therapy is begun six weeks after operation.

Campbell has employed a procedure similar in principle to that of Brett. The osteotomy is carried out at a lower level and includes the entire thickness of the bone. Wedge-shaped cortical grafts maintain the corrected position. Irwin has described a somewhat similar procedure.

Technic (Campbell).—A three-inch longitudinal incision is made along the patellar tendon and over the tibia. After subperiosteal exposure an osteotome is driven completely through the bone just below the level of the tibial tubercle. The proximal fragment is then elevated to correct the anterior tilt of the tibial plateau. This creates a wedge-shaped space at the osteotomy site, with its base anteriorly. To maintain this position, two wedge-shaped grafts are removed from the anterior surface of the same tibia through a separate incision. Two longitudinal slots are cut in the anterior portion of each frac

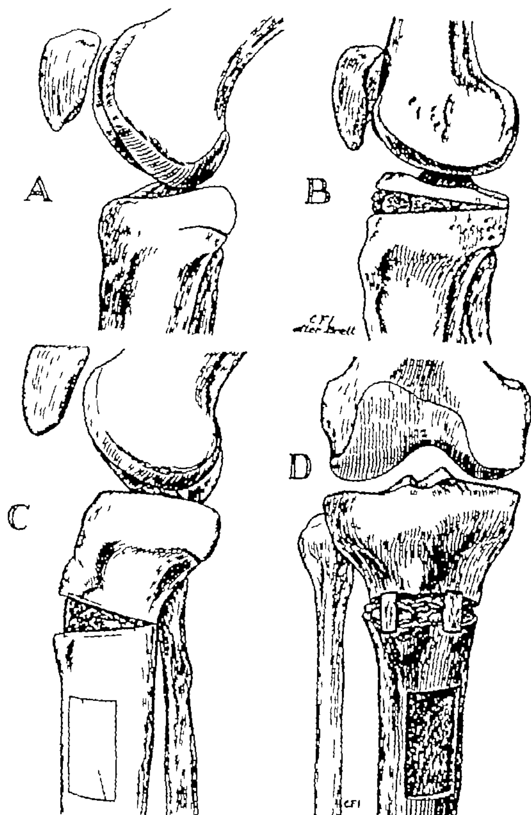


Fig. 388.—Operations for correction of genu recurvatum from arrested growth of anterior half of upper tibial epiphysis. *A* Articular surface of tibia slants forward as a result of continued growth of posterior half of epiphysis. *B* Osteotomy just below articular surfaces and elevation of surface fragment to normal articular plane. Position maintained by multiple small grafts of cancellous bone. (Redrawn from Brett, A. L. J Bone & Joint Surg. 17: 984, 1935.) *C* and *D* Subcondylar osteotomy and elevation of condyles, restoring articular surface of tibia to proper relationship with femur. Position maintained by wedge-shaped tibial grafts inserted in slots; intervening space filled with cancellous bone (modification of Brett procedure)

tured surface, one on the medial and one on the lateral aspect for the purpose of holding the grafts in situ The grafts are then inserted on edge into these slots, and the surrounding space is filled with bone chips. Roentgenograms should be made before closure to determine whether correction is complete

After Treatment.—The leg is immobilized in a cast from groin to toes, fixing the knee in an angle of 135 degrees' flexion and the cast is partially bivalved to allow for postoperative swelling Three weeks after operation, a new, snugly fitting cast of the same dimensions is applied the knee being held in slightly less flexion. Six weeks later walking is permitted with the support of a leather lacer brace extending from the groin to the ankle. Physical therapy and exercise are instituted after one month At this time, also the leather is removed from about the knee and active use of the knee is permitted. The brace usually is discarded at the end of another month.

Technic (Irwin) —(See Chapter XXII)

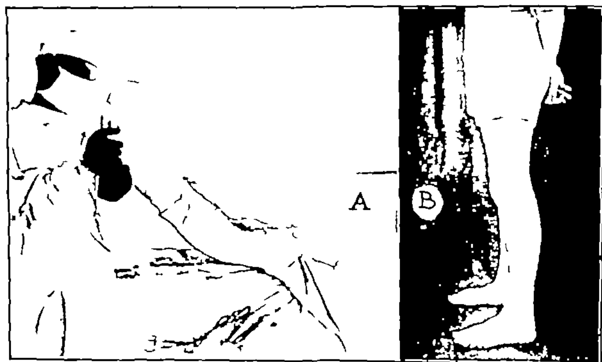


Fig. [illegible].—*A* Genu recurvatum deformity following removal of bone graft from tibia epiphysis probably injured with curette during process of removing cancellous bone from condyles. *B*, Stable knee, with no hyperextension and full range of flexion, following procedure illustrated in Fig. [illegible] *C* and *D*

PATELLA

Malunited fractures of the patella produce essentially the same symptoms as an advanced chondromalacia The degree of disability is proportionate to the amount of mechanical incongruity of the articular surface of the patella, and the scarring and marring of the contiguous surface of the femur Even in relatively recent cases, refracture and realignment, or partial excision is not the proper treatment. Patellectomy (Ch XIII) is the procedure of choice.

CONDYLES OF THE FEMUR

Malunion of the condyles of the femur as of the *tibia* distorts the anatomic contour of the articular surface of the knee Frequently the disability

is much more severe than that incident to malunited fractures of the condyles of the tibia. In fractures of the external condyle, the knee is fixed in external rotation, flexion and valgus, whereas in fractures of the internal condyle, the deformity is internal rotation, flexion and varus.

Malunion of Lateral Condyle of the Femur

Technic.—The joint is approached through a lateral incision, beginning four inches above the knee and extending downward to one inch below and slightly anterior to the head of the fibula. The iliotibial band is incised and the peroneal nerve, which passes over the head of the fibula, is avoided. The vastus lateralis muscle is incised and retracted anteriorly exposing the line of fracture. The capsule and synovial membrane are opened for visualization of the interior of the joint, that the accuracy of reduction may be determined



Fig. 317.—*A* Old malunited fracture of posterior half of lateral condyle of femur *B* After osteotomy and fixation of fragment with two stainless steel nails.

by inspection With an osteotome, the bone is refractured as near the line of union as possible, the popliteal vessels being carefully protected. The condyle is then grasped with bone-holding forceps and returned to its normal position and two Knowles pins are driven through the fragment into the internal condyle, crossing at an angle of 30 degrees. The pins should protrude through the opposite cortex. Two-view roentgenograms are made to verify the position of the pins and the fragment.

In fractures of the posterior portion of the lateral condyle the same lateral incision may be utilized although dissection is carried posteriorly The biceps tendon and peroneal nerve are exposed and retracted outward and backward. The posterolateral portion of the capsule is incised, exposing the malunited fragment of the condyle. The fragment, which is always displaced proximally may usually be refractured from above downward. After all fibrous adhesions

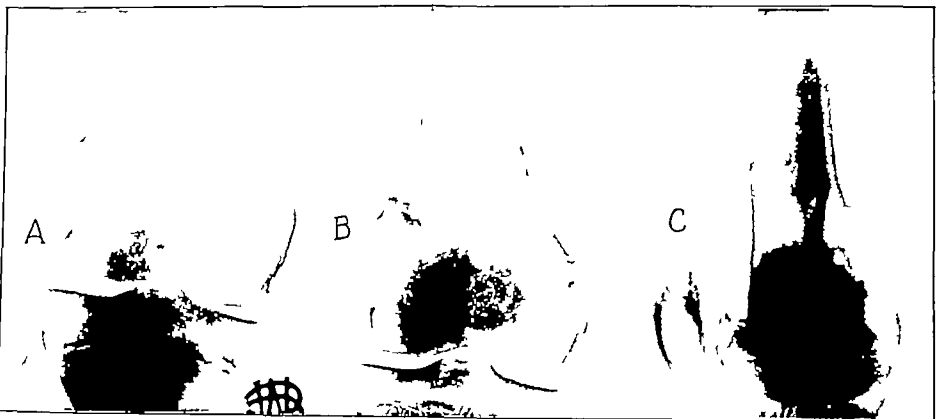


Fig. [illegible].—*A* Old injury to lower femoral epiphysis extreme valgus deformity from cessation of growth of outer half of epiphysis. *B* and *C* Excellent weight-bearing alignment restored by supracondylar osteotomy Defect on lateral side of osteotomy filled with cancellous bone from tibia and wedge cortical graft.

are freed, the fragment is brought into place with a towel clip and securely fixed with two nails driven in an anterior and medial direction a special inlay (Fig 68) facilitates the placing of the nails in the deep surfaces If the fragment is properly reduced there will be no deformity or flexion contracture of the knee.

After Treatment.—A plaster cast is applied from the toes to just above the crest of the ilium holding the knee in extension. At the end of two weeks the cast is bivalved and active and passive movements and physical therapy are instituted if fixation is firm, exercises may be carried out with overhead pulleys. Four weeks after operation the extremity is placed in a walking caliper brace with a drop ring catch at the knee, to allow motion on sitting but hold the joint in extension on walking An elevated shoe is fitted on the unaffected side and walking with the aid of crutches is permitted. Weight bearing should not be allowed until union is solid which usually requires eight weeks or more Free motion of the knee joint in the brace is begun at ten or twelve weeks postoperatively although the brace should not be removed until the end of the sixteenth week or longer Partial recurrence of the displacement is likely unless every precaution is taken

Malunion of Medial Condyle of the Femur

Correction of malunited fractures of the internal condyle may be effected by the same procedures required for the external condyle The exposure of this region is described on page 175

Malunion of Lateral and Medial Condyles

Malunited fractures of both condyles with pronounced displacement are seldom corrected by open reduction of each condyle as described above, unless the malunion is of relatively short duration and the patient is young When varus or valgus deformity is present transverse osteotomies should be carried out for realignment. If the contour of the articulation is irregular impairing function and causing symptoms, an arthroplasty or fusion may be advisable (Chapters XVII and XV)

SHAFT OF THE FEMUR

Malunited fractures of the shaft of the femur are observed with comparative frequency Operative correction is necessary in three types (1) those wherein the fragments are apposed though associated with extreme lateral and anterior bowing (2) those wherein the fragments overlap more than two inches yet are in excellent anatomic alignment and (3) those wherein the fragments are excessively overlapped and are bowed laterally and anteriorly If the malunion is of short duration union may be broken up manually and skeletal traction instituted to correct the shortening and malposition.

The question frequently arises during operations for malunited fractures of the shaft of the femur as to whether some form of internal fixation should be applied. When, in order to secure apposition, the periosteum is widely stripped from the bones circulation to the denuded area is definitely impaired and union is delayed. In this event, the onlay bone graft, as described for ununited fractures, is an excellent supplementary procedure, not only providing complete internal fixation but promoting osteogenesis. Removal of the graft of course, adds to an already extensive operation For fractures of the



Fig. 399.—*A* Malunited fracture of femur with little shortening but severe anterior and lateral bowing. *B* Alignment restored by osteotomy and replacement of fragments.

upper third of the femur, particularly in the subtrochanteric region, the appliances utilized in fixation of intertrochanteric fractures are applicable. If indicated, the metallic fixation may be supplemented by osteogenic procedures. We have had no experience with the use of intramedullary pins in malunited fractures of the femur in certain selected instances, their use may be warranted.

Although no large vessels are encountered in this region a tourniquet is always employed and left in situ until the wound is closed and a compression bandage applied. Use of the tourniquet greatly expedites the procedure and reduces shock from hemorrhage by maintaining a dry operative field.

The roentgenogram may distinctly reveal the line of fracture, yet at operation the ends of the fragments may be found so covered with callus that, even with extensive stripping of soft tissues, the line is recognized with difficulty To aid in identifying the fracture line, as well as in securing proper alignment of the contemplated osteotomy a Kirschner wire or a small pin may be inserted into the femur in the estimated line of fracture and the relative position of the pin and fracture site checked by roentgenograms. As an alternative, the thickened portion of the bone may be severed by a long oblique osteotomy, thus providing maximum apposition of the fragments after length has been regained.

To prevent comminution, the line of union between the fragments should be outlined with a drill If the holes are close together, union may be broken up with ease by severance of the intervening bone with a small chisel.

All operations for malunited fractures of the femur in adults should be performed with the patient on a fracture table. The affected extremity should be draped into the sterile field, the foot piece covered with sterile drapes, and the foot of the affected side tied to the stirrup By this procedure, the services of one assistant are eliminated trauma to the extremity is minimized, and a means of fixed traction established. If a wide range of manipulation or motion becomes necessary the foot may be released from the stirrup without fear of contamination.

Malunion With Angulation

In malunited fractures of the shaft of the femur with end-to-end engagement, the angulation and rotation are often induced by weight bearing before consolidation is complete If the patient is an adult and the fracture has been present no longer than eight weeks, manual force followed by skeletal traction may suffice to restore normal alignment. A few malunited fractures may be thus corrected as late as three months after injury The patient should be prepared for operation, and if forcible measures fail, open reduction should be carried out immediately When the fracture is observed after malunion is fully established, operation is the only recourse

Technic.—Exposure is accomplished through an appropriate anterolateral or lateral incision (p 173) The periosteum is incised longitudinally for a distance of three or four inches at the crest of the deformity With a No 19 motor drill, several holes are now made transversely through the bone. Since the femur is often exceedingly dense, this procedure saves time, avoids shock of the patient, and much effort on the part of the operator, in addition a direct transverse osteotomy is assured The bone is completely severed in the plane of the holes, an osteotome being used to form a broad even surface of maximum impingement. The fragments may be notched by a motor saw to secure more

definite interlocking although this results in some shortening of the limb, increases operating time and usually is unnecessary The deformity is then corrected by manual force

In the majority of cases particularly in fractures of the upper half of the femur, reduction may be unstable and maintenance of the end to-end engagement and proper alignment doubtful If the bone is of good quality, metallic fixation alone may be sufficient A strong six hole plate which extends well proximal and distal to the fracture site is applied, one should be sure that the screws adequately engage the opposite cortex. If the bone is sclerotic, this procedure may be augmented by the use of cancellous bone grafts laid parallel and opposite to the plate These grafts are not transfixed to the shaft of the femur but lie loosely in the periosteal envelope.

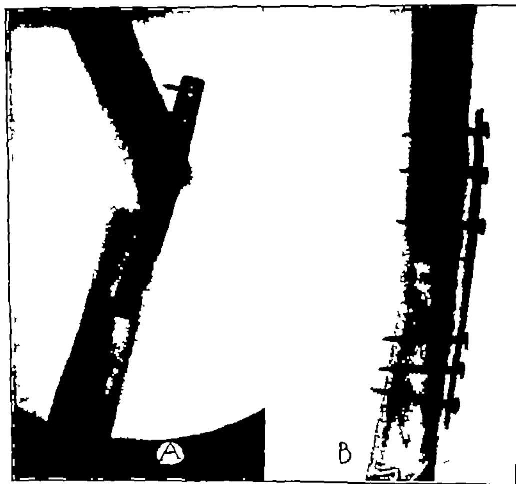


Fig. 400—A Malunited fracture of shaft of femur Fixation with Vitallium plate elsewhere; apparently screws were too short and holes for insertion of screws too large, with consequent loss of fixation. B, Anatomic reduction fixation and osteogenesis by onlay tibial graft held in place by six Vitallium screws.

If the soft tissue parts are under excessive tension the ends of the fragments may be resected provided the total shortening of the extremity does not exceed one inch In this manner the correction is completed at one procedure. Or as a less desirable alternative anatomic alignment is not attempted at this time, being restored gradually by means of skeletal traction

After Treatment.—With the hip and knee in 150 degrees flexion and the hip in 160 degrees' abduction a plaster cast is applied from the nipple line to the knee on the unaffected side and to the toes on the affected side

At the end of the fourth or fifth week in adults, and the third week in children, the cast is removed and the exact contour and alignment determined by examination and the roentgenogram. Because of the atrophy of the soft tissues a more closely fitting cast is applied to insure better fixation. At the end of eight weeks the cast is removed if union is solid, the extremity is placed in a Thomas walking caliper brace with a tight leather corset around the thigh, and a joint at the knee for motion on sitting and fixation on walking. The brace should be worn for a period of two to three months. Should union not be firm, a walking cast is applied from the toes to just above the crest of the ilium or in obese individuals, to the chest.

Malunion With Excessive Overlapping in Good Alignment

Experience is required to distinguish between those fractures united in satisfactory alignment wherein surgery should and should not be employed. In *general, however, the following principles may be loosely applied.* In *young*

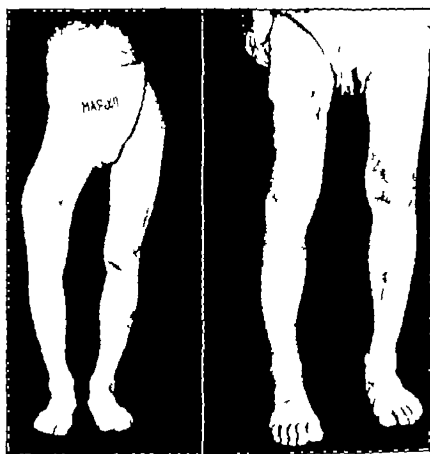


Fig. 401.—Before and after osteotomy for extreme malunion of lower third of femur.

children the stimulus of trauma may produce an overgrowth which will overcome one-half to three-fourths inch of shortening. Ordinarily this takes place within six to nine months after the fracture, thereafter little or no improvement of the discrepancy in length of the extremities may be anticipated. The procedure is more often indicated in young adults when the length of the leg is diminished more than one and one-half inches. The operation is a formidable one and union may be delayed, prolonging convalescence. Further there is a

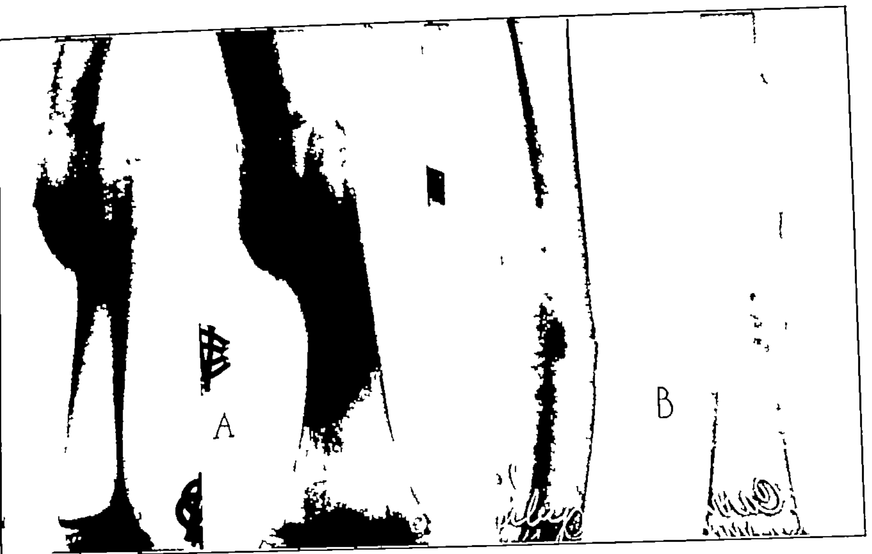


Fig. 402.—*A* Malunion of fracture of femur with wide overlapping of fragments. *B* Replacement of fragments in satisfactory position following breaking up of malunion and resection of small amount of bone from each fragment. Three-fourths inch shortening with completion of procedure at one operation and end-to-end engagement of fragments preferable to long period of hospitalization following osteotomy and use of skeletal traction, with possibility of delayed union or nonunion.

possibility of permanent impairment of function in the knee. If osteoporosis is extensive, weight bearing should be practiced prior to operation until the osseous structure has been partially restored and pain and swelling have disappeared. The prospect of success is excellent if the patient is willing and able to cooperate for a sufficient length of time

In elderly individuals, because of the danger of surgical shock or ultimate nonunion, operation is not justifiable if union is solid rather the shortening should be compensated for by an elevation of the shoe.

The technic is essentially identical to that described below

Malunion With Excessive Overlapping and Bowing or Rotation

In malunited fractures of the shaft of the femur of this type angulation and overlapping may be so extreme that growth cannot compensate for the severe deformity even in children under ten years of age In this event, operation is always warranted, provided the patient is a good surgical risk. There are many cases, however wherein one might be justified in under taking surgical correction of a deformity of only moderate degree Here also discrimination is necessary As a rule a procedure of such magnitude is advisable only in young adults with excessive angulation and more than one and one half inches shortening

If the fracture is of relatively recent origin, manual refracture may be possible, length and alignment being restored by skeletal traction. If union does not take place, a bone-graft procedure is carried out.

For the more severe deformities of long standing a two-stage operation may be necessary At the first stage, union is broken up in an oblique plane by osteotomy thereafter, length is restored by skeletal traction. Finally, union in good position and alignment is secured by a bone-grafting procedure.

Technic—The fracture site is exposed by an appropriate lateral, or anterolateral incision (p 173) The line of fracture must be carefully inspected and compared with the roentgenogram that the osteotomy may be placed as near the original site as possible Usually, the upper fragment is lateral and anterior to the lower and may be readily visualized if the malunion is of not more than six months' to one year s duration. The periosteum is incised and stripped from the lateral surface of the upper fragment. With a No 19 drill union between the fragments is outlined, thus avoiding the possibility of producing a new fracture at an undesirable site. Or if union is firmly organized, a Z-shaped or oblique osteotomy may be performed, without regard to the line of fracture In either event, holes are made, preferably with a motor drill, as this permits more effective and rapid execution. The bone is often so dense that the use of the hand drill is not only time consuming but is extremely fatiguing One should proceed cautiously in order to prevent injury to important nerves and vessels on the medial side of the bone An osteotome one-half inch in width is used to connect the holes and complete the separation of the fragments

One-fourth to one half inch of bone is next resected from each fragment with a hand saw There are several reasons for this procedure (1) usually the ends of the fragments are sclerotic and must be excised to comparatively normal bone (2) the surface thus formed permits a more stable and accurate

apposition (3) if malunion is of long duration, excision of the ends makes apposition less difficult and buckling or recurrence of the deformity less likely, and (4) if the fragments are approximated under tension, the bones will undergo atrophy from pressure necrosis.

In the less severe deformities, approximation and firm interlocking of the fragments may be possible Even at the expense of one-inch shortening the reduction should be completed at one operation if feasible Fixation and osteogenesis are provided by metallic plates and grafts (pp 374, 610)

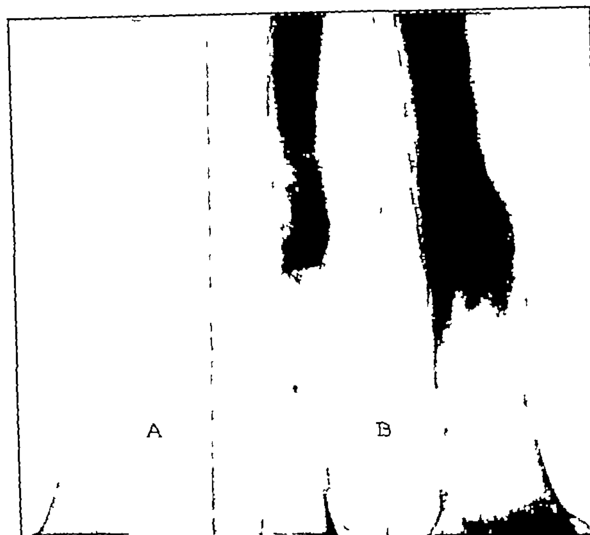


Fig 463 — A Malunion of fracture of femur with wide overlapping of fragments. End-to-end apposition secured following osteotomy and resection of sclerotic portion of ends of fragments. Fixation by onlay bone graft. B Sixteen months postoperatively

In some cases reduction may be impossible without an undesirable degree of stripping of the soft tissues and wide resection of the ends of the fragments. After severance of the union, a Kirschner wire is inserted through the condyles of the tibia or femur, depending upon the location of the fracture, and fifteen to thirty pounds of skeletal traction applied Thus, the normal length of the limb may be almost completely restored. Care should be taken not to distract the fragments, as this will lead to nonunion. If a satisfactory reduction is obtained by skeletal traction, a cast may be applied and after treatment carried out as described previously (p 551) or an onlay bone-graft operation may be

undertaken in adults, not only to effect a more adequate reduction, but to promote osteogenesis and insure a relatively rapid union

After Treatment.—See p 645

These measures are uniformly successful in children. In a large majority of cases, young adults also obtain gratifying results, although there may be some limitation of motion in the knee because of the necessarily prolonged immobilization Nonunion ordinarily does not occur in children, but is the *most serious consideration in adults* the danger of nonunion is reduced however, if the precautions just described above are observed

UPPER THIRD OF THE FEMUR

As the upper fragment is relatively short, frequently tension of the psoas and iliacus muscles, and the abductor muscles of the hip joint causes extreme anterior displacement and outward bowing Unless one is cognizant of this fact and takes precautionary measures, recurrence of the malunion after correction is inevitable

Technic.—The lateral incision (p 179) begins just above the greater trochanter and passes downward over the center of the trochanter to below the level of the fracture The line of fracture is then severed, as described for malunited *fractures of the shaft of the femur* If the upper fragment cannot be adducted into proper alignment, the attachment of the abductor muscles to the greater trochanter may be separated with a scalpel or an osteotome.

When angulated, the fragments are merely realigned. In the presence of displacement and overlapping, apposition and length are secured by manual reduction and traction. Maintenance of reduction at this stage is considerably facilitated if the feet are tied in the stirrups of a fracture table. For fractures *within two inches of the lesser trochanter the appliances applicable to* intertrochanteric fractures may be utilized particularly the Blount blade plate. For fractures at the junction of the middle and upper thirds, an ordinary plate of a size and length comparable to the size of the bone, perhaps supplemented *by bone grafts is appropriate.*

If the soft tissues are so severely contracted that reduction cannot be accomplished the wound should be closed and length restored by skeletal traction.

After Treatment.—Immobilization is effected by means of a long spica cast, the knee and hip being held in 150 degrees flexion. For subtrochanteric fractures, internal fixation may be sufficiently strong to obviate the necessity for a cast. For other fractures, the cast should be maintained for a period of eight weeks. If union is not solid at the end of that time, the extremity may be brought gently toward the neutral position and further immobilized in a spica cast As a rule, union is sufficiently solid to permit walking with crutches twelve to fourteen weeks postoperatively All support may usually be discarded at the end of four or five months.

MALUNITED TROCHANTERIC FRACTURES OF THE FEMUR

Malunited fractures in the region of the trochanters may be divided, for the purpose of description into the following types (1) those with external or internal rotation coxa vara, and shortening of approximately one inch, (2)

those with external or internal rotation severe coxa vara, and decrease in length of two or more inches and (3) malunion of the lesser trochanter

In the presence of external or internal rotation coxa vara and shortening of one inch no attempt is made to reduce the shortening other than by angulation at the osteotomy site The rotation and coxa vara deformity are corrected by subtrochanteric osteotomy

Subtrochanteric Osteotomy for Coxa Vara and Rotation Deformity

The technic of this procedure, which is applicable to many conditions, is described in the chapter on Ankylosis and Deformity A variation of the routine technic is described under Compensatory Trochanteric Osteotomy for Malunited Slipped Upper Femoral Epiphysis (Chapter XIII)

Intertrochanteric Osteotomy for Coxa Vara, Rotation and Shortening

The majority of patients with malunited trochanteric fractures are elderly individuals. In many of these, the disability had best be accepted without recourse to surgery Even in the better risk patients, no attempt should be made to regain length instead the procedure should be limited to correction of only the coxa vara and rotational deformity

In trochanteric fractures united in external or internal rotation with severe coxa vara deformity and a decrease in length of two or more inches, correction can often be accomplished only by a two stage operation and the use of skeletal traction If the rotation is extreme and an attempt is made to correct the rotation as well as the coxa vara deformity and the decrease in length at the same time, there will be relatively little apposition of the osseous surfaces and union may be delayed indefinitely The first procedure should consist of correction of the shortening and coxa vara without regard to the rotation at a second operation the rotation may be corrected by supracondylar osteotomy A two-stage procedure of such magnitude, obviously is applicable only to young adults or to children. The correction of this type of malunion is a most difficult problem and calls for much endurance and fortitude on the part of both patient and surgeon

Technic.—Beginning one inch above the upper extremity of the greater trochanter a lateral longitudinal incision is extended down over the shaft of the femur a distance of three or four inches. A curved lateral (Watson-Jones) incision also provides excellent exposure.

The trochanteric attachments of the gluteus medius and maximus muscles are severed and retracted, and the shaft of the femur exposed for two inches below the trochanter An osteotome is now inserted into the upper portion of the trochanter at an angle of 30 degrees to the shaft and driven distally and medially producing an oblique fracture three or four inches in length, which either follows the line of the fracture or simulates the line of a peritrochanteric fracture In some cases, after considerable dissection about the greater trochanter and possibly subcutaneous tenotomy of the adductor tendons, it may be possible to realign the fragments in relatively satisfactory position, and insert internal fixation as for trochanteric fractures Thus, the procedure is completed at one operation. Otherwise, a Kirschner wire is inserted into the lower end of the femur

After Treatment.—A well padded plaster cast is applied from the nipple line to the ankle on the affected side and to the knee on the normal side, the knee and hip being held in 150 degrees flexion After three days, the portion of the cast from the ankle to just above the Kirschner wire is bivalved and the anterior half removed. Traction, beginning with fifteen pounds of weight and gradually increasing to thirty pounds, is maintained until the maximum length of the extremity has been restored and the coxa vara deformity corrected. Thereafter approximately fifteen pounds of traction should be continued for a period of three or four weeks. From one to one and one-half inches' increase in length may generally be secured by this method

At the end of three to four weeks a second plaster cast is applied from the nipple line to the toes on the affected side and to the knee on the normal side No attempt is made to correct rotation. This cast is removed at the end of the eighth week if union is not sufficiently stable at that time, the extremity is placed in another cast. If union is adequate, a Thomas caliper brace with a drop ring joint to allow motion at the knee on sitting is fitted and active and passive motion with physical therapy are begun. The brace is discarded after three months

When consolidation is complete and active motion of the knee ranges from extension to 130 degrees' flexion, the rotation is corrected by a supracondylar rotation osteotomy at the knee (Ch. XVI) The limb is then held in a cast from the toes to the crest of the ilium for a period of three to four weeks. The treatment thereafter is identical with that described previously

MALUNION OF CERVICOTROCHANTERIC FRACTURES OF THE FEMUR IN CHILDREN AND ADULTS

This is a fracture at the junction of the trochanter and neck of the femur In children, fractures of the neck of the femur occur most often in this location, and are not unusual in adults. On the posterior aspect, the fracture is always extracapsular as the posterior portion of the capsule of the hip joint does not invest the extreme outer third of the neck. On the anterior aspect the fracture line may be just external to the capsule, or may extend within the capsule for a short distance. Unless properly treated, malunion is inevitable and results in a coxa vara of 90 degrees with external rotation of the distal fragment and approximately two inches loss of length In children shortening may be slight when union first takes place but increases with growth, and may ultimately reach three inches even though the epiphyses are not involved. This decrease apparently is caused by the partial disability of the extremity which results in deficient stimulation of the epiphyses from normal stress and pressure. Correction of this deformity is notably difficult to maintain in children in young adults the prospect of securing normal alignment and function is much more favorable In elderly patients subtrochanteric osteotomy (Ch. XVI) alone is employed for correction of the deformity Although only a relative increase in length is obtained by this means, function is materially improved.

Technic.—The fracture site, the trochanters, and the proximal two inches of the shaft of the femur are exposed through a curved lateral incision between the tensor fasciae femoris and gluteus medius muscles (p 150) Because of

the internal rotation the fractured surface of the trochanter faces antero-medially thus, a wedge-shaped space with its base anteriorly is formed between the fragments. This space is ordinarily filled with fibrous tissue.

The fibrous tissue between the fragments is excised *down to normal* bone and the posterior osseous union is severed with an osteotome. Apposition of the surfaces and correction of the deformity is secured by abduction and rotation of the distal fragment internally while a maximum amount of traction is applied to the leg If difficulty is encountered in abducting the distal fragment tenotomy of the adductors may be necessary (Ch XVI) To facilitate correction of the rotation deformity the gluteal attachments to the *greater trochanter may* be severed

After ten minutes of traction an anteroposterior roentgenogram is made on the fracture table to demonstrate the degree of correction. If the normal angle has been restored some form of internal fixation such as the Blount blade plate, or the Jewett or Neufeld nail, is applied by a technic similar to that described for intertrochanteric fractures (p 426) In children the upper femoral epiphysis should not be violated. If some degree of shortening or coxa vara deformity remains, internal fixation is not employed rather, skeletal traction is instituted by means of a Kirschner wire through the lower extremity of the femur as described for malunited fractures of the trochanteric region or the Hoke-Martin traction apparatus is used, with or without skeletal traction. Two to three weeks later after restoration of normal alignment, the cast is removed and internal fixation is applied.

After Treatment.—If correction is not completed at operation, the post operative measures described for malunited intertrochanteric fractures with excessive shortening may be carried out. If complete correction is secured and maintained by internal fixation a cast should be applied and retained for a period of at least eight weeks. Under the most careful after treatment a decrease in the angle is not uncommon, even after union is apparently solid.

In children, the results of this operation are disappointing as only a moderate improvement may be secured. Efficient treatment of the fresh fracture, therefore, is of prime importance. In young adults, function is materially improved, although rarely if ever is the normal angle of the neck fully restored or normal length obtained

PELVIS

With few exceptions, the only fractures of the pelvis wherein malunion occurs, warranting correction by open surgery are those involving the acetabulum. Operation may afford improvement of function with relief of pain in the following three types of malunion (1) fracture of the acetabulum with central dislocation (2) comminution of the acetabulum with traumatic arthritis and (3) fracture of the superior rim of the acetabulum with dorsal dislocation

Malunion of the Acetabulum With Central Dislocation

Fortunately with modern methods of treatment, malunited fractures of the acetabulum with central dislocation of the hip are seldom encountered If the fracture has become solidly fused in malposition, the advisability of any surgical procedure other than a subtrochanteric osteotomy to correct an exist

After Treatment.—A well padded plaster cast is applied from the nipple line to the ankle on the affected side and to the knee on the normal side, the knee and hip being held in 150 degrees flexion. After three days, the portion of the cast from the ankle to just above the Kirschner wire is bivalved and the anterior half removed. Traction, beginning with fifteen pounds of weight and gradually increasing to thirty pounds, is maintained until the maximum length of the extremity has been restored and the coxa vara deformity corrected. Thereafter approximately fifteen pounds of traction should be continued for a period of three or four weeks. From one to one and one-half inches increase in length may generally be secured by this method

At the end of three to four weeks a second plaster cast is applied from the nipple line to the toes on the affected side and to the knee on the normal side. No attempt is made to correct rotation This cast is removed at the end of the eighth week, if union is not sufficiently stable at that time, the extremity is placed in another cast. If union is adequate, a Thomas caliper brace with a drop ring joint to allow motion at the knee on sitting is fitted and active and passive motion with physical therapy are begun. The brace is discarded after three months.

When consolidation is complete and active motion of the knee ranges from extension to 130 degrees flexion the rotation is corrected by a supracondylar rotation osteotomy at the knee (Ch XVI) The limb is then held in a cast from the toes to the crest of the ilium for a period of three to four weeks. The treatment thereafter is identical with that described previously

MALUNION OF CERVICOTROCHANTERIC FRACTURES OF THE FEMUR IN CHILDREN AND ADULTS

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Technic.—The fracture site, the trochanters, and the proximal two inches of the shaft of the femur are exposed through a curved lateral incision between the tensor fasciae femoris and gluteus medius muscles (p 150) Because of

the internal rotation, the fractured surface of the trochanter faces anteromedially thus a wedge-shaped space with its base anteriorly is formed between the fragments This space is ordinarily filled with fibrous tissue

The fibrous tissue between the fragments is excised down to normal bone, and the posterior osseous union is severed with an osteotome. Apposition of the surfaces and correction of the deformity is secured by abduction and rotation of the distal fragment internally while a maximum amount of traction is applied to the leg If difficulty is encountered in abducting the distal fragment tenotomy of the adductors may be necessary (Ch. XVI) To facilitate correction of the rotation deformity the gluteal attachments to the greater trochanter may be severed

After ten minutes of traction an anteroposterior roentgenogram is made on the fracture table to demonstrate the degree of correction. If the normal angle has been restored some form of internal fixation, such as the Blount blade plate or the Jewett or Neufeld nail, is applied by a technic similar to that described for intertrochanteric fractures (p 420) In children, the upper femoral epiphysis should not be violated If some degree of shortening or coxa vara deformity remains, internal fixation is not employed rather, skeletal traction is instituted by means of a Kirschner wire through the lower extremity of the femur as described for malunited fractures of the trochanteric region, or, the Hoke-Martin traction apparatus is used with or without skeletal traction Two to three weeks later after restoration of normal alignment the cast is removed and internal fixation is applied.

After Treatment.—If correction is not completed at operation the postoperative measures described for malunited intertrochanteric fractures with excessive shortening may be carried out. If complete correction is secured and maintained by internal fixation, a cast should be applied and retained for a period of at least eight weeks. Under the most careful after treatment a decrease in the angle is not uncommon, even after union is apparently solid.

In children, the results of this operation are disappointing as only a moderate improvement may be secured. Efficient treatment of the fresh fracture, therefore is of prime importance. In young adults, function is materially improved, although rarely if ever is the normal angle of the neck fully restored or normal length obtained

PELVIS

With few exceptions, the only fractures of the pelvis wherein malunion occurs, warranting correction by open surgery, are those involving the acetabulum Operation may afford improvement of function with relief of pain in the following three types of malunion (1) fracture of the acetabulum with central dislocation, (2) comminution of the acetabulum with traumatic arthritis and (3) fracture of the superior rim of the acetabulum with dorsal dislocation.

Malunion of the Acetabulum With Central Dislocation

Fortunately with modern methods of treatment malunited fractures of the acetabulum with central dislocation of the hip are seldom encountered If the fracture has become solidly fused in malposition, the advisability of any surgical procedure other than a subtrochanteric osteotomy to correct an exist

ing adduction deformity is questionable. This is particularly true if the *patient is engaged in a laborious occupation* If motion is desired, a modified Whitman or Colonna reconstruction operation is employed.

The following technic is similar in principle to that described by Whitman for ununited fractures of the neck of the femur differing only in the attack on the neck and the formation of a new acetabulum.

Technic.—The hip joint is exposed by an anterior iliofemoral incision (p 146) which curves distally and posteriorly to the trochanter The neck of the femur is severed with as much of the head as possible. A gouge is driven between the neck and acetabulum and the separation is completed with a large curved wood-carver s chisel. The neck of the femur is dislocated and the medial end remodeled into a round smooth articular surface. A new acetabulum is then reconstructed as for arthroplasty (Ch. XVII) this may necessitate removal of a portion of the head of the femur which has remained undisturbed within the acetabulum A Vitallium cup or a strip of free fascia lata is interposed to form a double lining for the new joint, and the neck of the femur is reduced into the acetabulum The greater trochanter and upper two inches of the shaft are next exposed by subcutaneous dissection and retraction of the posterior border of the incision, and the greater trochanter is severed its gluteal attachments remaining intact. The hip is placed in extreme abduction while the severed trochanter with its muscular attachments is pulled distally by means of a tenaculum and reattached to the shaft of the femur as low as possible, the lateral surface of the femur at this point *having first been denuded with an osteotome.*

After Treatment.—See p 663

If the neck is too short to permit the Whitman operation, a modified Colonna reconstruction may be carried out. By this method, the entire neck is removed, the acetabulum is remodeled and the trochanter reduced into the newly formed acetabulum (p 664) The Colonna operation is advantageous in that the interposition of tissue is not required

Malunion of Comminuted Fractures of the Acetabulum

Malunion after comminution of the acetabulum usually must be corrected by a complete arthroplasty (Ch XVII) or arthrodesis (Ch. XV)

Malunion of Fracture of the Superior Rim of the Acetabulum With Dorsal Dislocation

The treatment for malunited fractures of the superior margin of the acetabulum with dislocation of the head is described in Chapter VII

SPINE

Compression fractures of the vertebrae are frequently overlooked at the time of injury and, as a consequence, union takes place in malposition. Further in a small number of cases, some degree of compression of the body of a vertebra may persist despite adequate treatment and continue to cause sufficient pain and *disability to warrant surgical intervention.* As a rule, a fair trial of conservative treatment, such as the use of a Bradford frame with traction followed by a long Taylor spine brace, is advisable. If pain persists,

spinal fusion is the treatment of choice. Two vertebrae above and below the one affected are fused by any of the methods described in the chapter on Arthrodesis.

Occasionally, following fractures of the spine which involve the pedicles or articular facets, root pains limited to the distribution of one or two segments may warrant posterior root resection in addition to fusion These procedures may be carried out at one operation.

CLAVICLE

Open reduction of malunited fractures of the clavicle is unnecessary unless there is extreme overlapping of the fragments with shortening of the shoulder girdle or osseous pressure on the brachial plexus. In the latter condition, excision of excess bone from the posterior and inferior surfaces may suffice. Occasionally open reduction may be indicated for cosmetic reasons. Malunited fractures which generally cause disability are those of the inner third and extreme outer third. The bones must be refractured in the line of malunion, or a plastic osteotomy must be carried out to elongate the clavicle as much as possible. The operative technic thereafter is identical to that for ununited fractures of the clavicle. In fractures of the outer third associated with rupture of the coracoclavicular ligament, a procedure similar to that required for acromioclavicular dislocations is indicated

HUMERUS

Malunion of the Anatomic Neck of the Humerus

Malunited fractures of the anatomic neck of the humerus, if accompanied by a severe painful traumatic arthritis, should be treated by fusion of the shoulder (Ch. XV) the Jones tendoplastic procedure (p 472), or by acromioplasty (Ch. XIII) Severe fractures of the shoulder are frequently followed by some limitation of motion particularly in elderly individuals this alone however is rarely sufficient for operative treatment. Occasionally, manipulation of the shoulder may suffice in lieu of surgical correction

Malunion of the Surgical Neck of the Humerus

A considerable deformity in this region may be commensurate with adequate function. In the presence of severe anterior displacement or angulation of the lower fragment, disability may be so extreme as to necessitate surgery

Technic.—The incision is made on the anterolateral aspect of the shoulder beginning at the outer third of the clavicle and extending distally four inches in line with the anterior border of the deltoid muscle. The deltoid and pectoralis major muscles are separated. If exposure is not ample, the attachment of the deltoid to the clavicle is severed and the muscle turned outward. Excess callus is removed from the bone and the line of union is divided with an osteotome. A bone skid is then used to lever the fragments into anatomic relation. Usually the reduction is stable otherwise, internal fixation may be employed.

After Treatment.—The shoulder is maintained in 135 degrees abduction by means of a plaster cast extending over the body and arm or a splint, such as Campbell's traction humerus splint, is applied with only an amount of

tension necessary to immobilize the extremity and fracture. After four weeks, union is usually well advanced, permitting active and passive movements and physical therapy, although protection between exercise periods is continued for an additional two to three weeks.

Malunion of the Upper Third of the Humerus

In malunited fractures of this region the deformity is usually medial bowing with some degree of anterior or posterior angulation. There may be a persistent neuritis, and motion is limited in abduction and adduction. The medial bowing prevents approximation of the elbow to the chest.

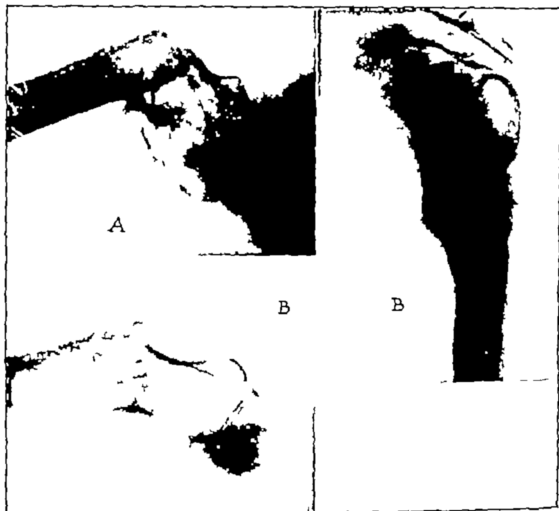


Fig. 404.—*A* Malunion of fracture of upper third of humerus, with extreme angulation which prevented apposition of elbow to chest. *B* Following osteotomy and alignment of fragments, normal range of motion restored. Recurrence of moderate angulation apparent in lateral view did not impair result.

Technic.—The fracture site is exposed through a three-inch anterolateral incision (p. 181) over the apex of the deformity. Extensive stripping of the periosteum is unnecessary. Union is severed by means of an osteotomy through the highest portion of the crest of the bow and the deformity is corrected. Thereafter the humerus should easily approximate the chest.

After Treatment.—A hanging cast is applied from the axilla to the palm. Until the postoperative reaction subsides, the arm is immobilized on an abduction

humerus splint thereafter, the latter is discarded and treatment carried out by the hanging cast as for a fresh fracture

Although the roentgenogram *may reveal an imperfect anatomic restoration*, the functional result is excellent.

Malunion of the Middle Third of the Humerus

Unless there is gross angulation *malunited fractures of this region seldom* require surgery, as variations in length rotation and moderate angulation do not impair function to the same extent as in a weight bearing extremity, or in the forearm

The technic of operation embodies principles *similar to those followed in* the correction of malunion of other long bones. Since the fragments of the shaft of the humerus often fail to unite, in the majority of cases, an onlay bone graft, or possibly a Vitallium plate should supplement the correction of deformity

LOWER EXTREMITY OF THE HUMERUS

Malunited fractures of the lower third of the humerus may be classified *as follows* (1) T fractures of the condyles, (2) comminuted fractures of the articular surface of the elbow joint, (3) fractures of the condyles (a) medial condyle (b) epicondyle, (c) lateral condyle (4) supracondylar fractures.

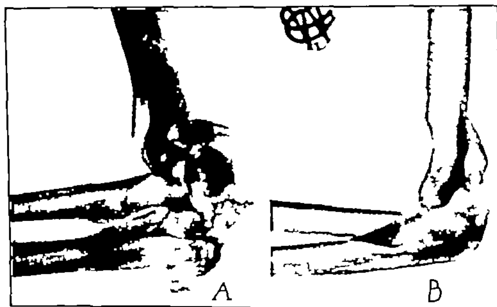


Fig. 404.—*A* Extensive compound comminuted fracture involving all structures of the elbow joint. Union in malposition, but no infection. *B* After arthroplasty *re-establishment* of satisfactory range of motion.

Surgical procedures for malunited fractures about the elbow can seldom be undertaken with impunity as often a persistent reaction which further increases *disability is incited* by any operation This reaction may be manifested by an excessive formation of scar tissue around the joint, or an over production of callus. In an attempt to obviate this complication, some surgeons advocate postponing operation in recent malunited fractures until the reparative process is complete. We are, ordinarily not *in accord with this* opinion how

ever, any operation which involves extensive dissection of the soft tissues and correction of malunion should not be considered unless deformity and disability are extreme.

Malunion of T Fractures or Comminuted Fractures of the Articular Surface

Even though efficient treatment is carried out in fresh fractures of these types ankylosis may ensue or motion may be limited to a degree which prevents practical use. Or, because of incongruity of the articular surface, pain and disability may be extreme. Reduction and restoration of motion are, as a rule, impossible by simple refracture arthroplasty (Ch. XVII) alone will suffice. Occasionally arthroplasty must be preceded by a plastic osteotomy



Fig. 404.—Old comminuted fracture of elbow joint. Open reduction elsewhere. Limited range of painful motion. *B* Excellent range of motion restored by arthroplasty Note amount of joint space in lateral view

Condyles of Humerus

In malunited fractures of the humeral condyles in children, one must consider not only the immediate deformity but the probability of an increase in the deformity as growth progresses. The advisability of operation depends upon the age of the patient and the duration of the malunion. *If attempts to effect closed reduction have been unsuccessful or the fracture has been neglected*, the rapid formation of callus and scar tissue may present a status of malunion after two or three weeks. Even the lapse of a few weeks from the time of fracture materially alters the prognosis with rare exceptions, although a perfect anatomic reduction is secured, there may be some evidence of disturbed epiphyseal growth

Malunion of Medial Condyle

Malunited fractures of the medial condyle of only a few weeks duration may be corrected by refracture. If the callus is still pliable and easily removed

from the displaced fragment and the line of fracture reduction and fixation may be effected in a manner similar to that described for fresh fractures. Mal union of several months' or years' duration can seldom be corrected by re-fracture and reduction Growth is already materially disturbed, and surgical procedures which involve epiphyseal lines will add to the deformity as growth continues. After maturity if deformity and limitation of motion are extreme plastic osteotomies may restore the general alignment of the joint, or arthroplasty may be indicated

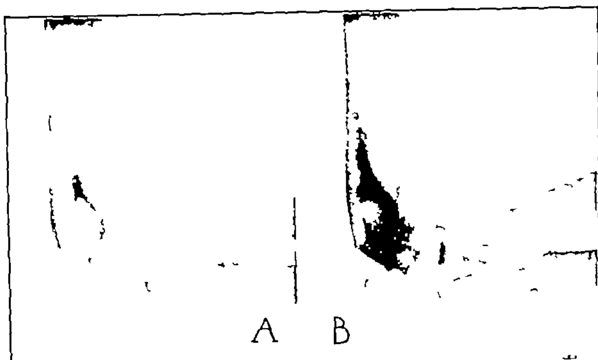


Fig 407 —A, Old fracture of a portion of articular surface of lateral humeral condyle union in a position which blocked flexion. B Fragment excised. Range of motion improved.

Malunion of Medial Epicondyle

In malunited fractures of the epicondyle, surgical treatment is *seldom* required for correction of the bony deformity Function approaches normal unless there is an associated ulnar neuritis. Transposition of the ulnar nerve to an anterior route (p 773) will usually relieve symptoms

Malunion of Lateral Condyle

Malunion of fractures of the external condyle of the humerus in children is *far* more disabling then malunion of a medial condylar fracture. As a rule a status of nonunion exists, with a consequent cessation of growth on *the lateral* side of the joint and an increase in the carrying angle of the elbow This *may* lead to a tardy ulnar palsy and neuritis, with a partial or complete physiologic block of the nerve *in addition* to the dysfunction associated with the bony deformity of the elbow Operative *measures* are discussed under nonunion of this fracture and tardy ulnar palsy (pp 691 773)

Malunited fractures of either condyle are *rarely treated* by refracture and internal fixation because of *the danger* of a reaction about the joint and the likelihood of an increase in disability Arthroplasty is the only procedure

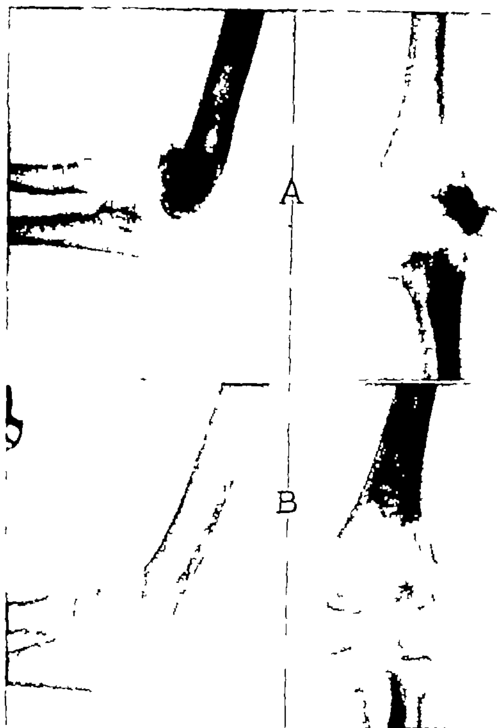


Fig 408.—*A*, Malunited fracture of external condyle of eight months' duration, in child aged five years. *B*, Two years after open reduction and internal fixation, growth of the external condyle is progressing at essentially the same rate as medial condyle no increase in carrying angle.

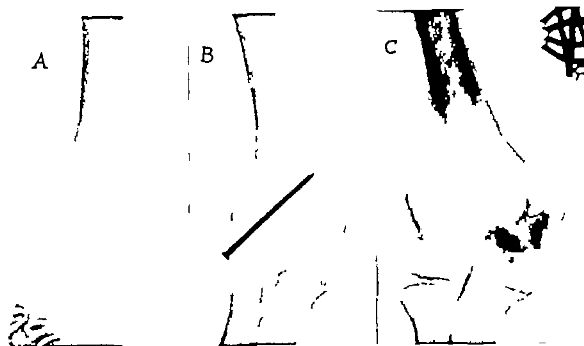


Fig. 409.—*A*, Malunited fracture of external condyle of humerus of six weeks' duration, in child aged eight years. *B* One month after open reduction and internal fixation. *C* Three years after operation, patient has obvious growth disturbance with beginning cubitus valgus deformity

Fig 410.—*A* Old fracture of external condyle of humerus sustained in childhood. Despite maldevelopment, carrying angle and function of joint practically normal. *B* Excision and remodeling of external condyle improved external appearance of elbow and in no way impaired function.

which offers a prospect of satisfactory function, but should be undertaken only when motion is excessively limited and then not until full growth is attained

Supracondylar Fractures of the Humerus

The treatment of malunion of supracondylar fractures depends upon the extent of the displacement, the amount of rotation the degree of limitation of motion, and the age of the patient. *The types of deformity may be classified as follows* (a) Posterior displacement of the distal fragment, with or without

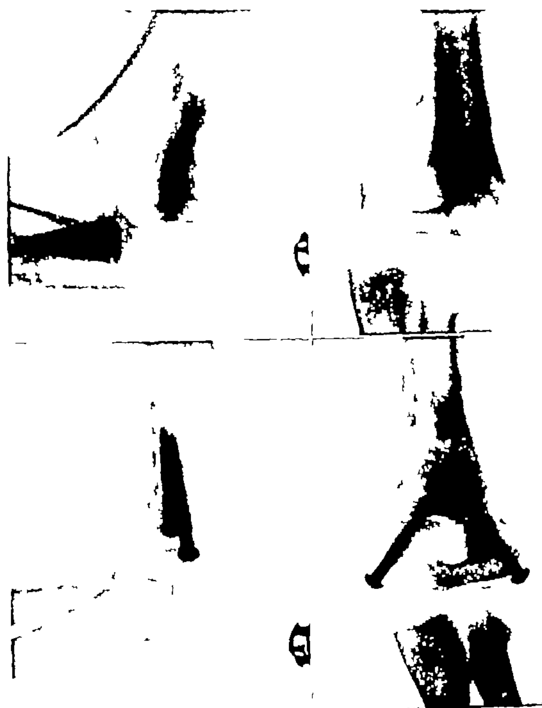


Fig. 411.—Malunited supracondylar fracture of humerus treated by open reduction and internal fixation with screws.

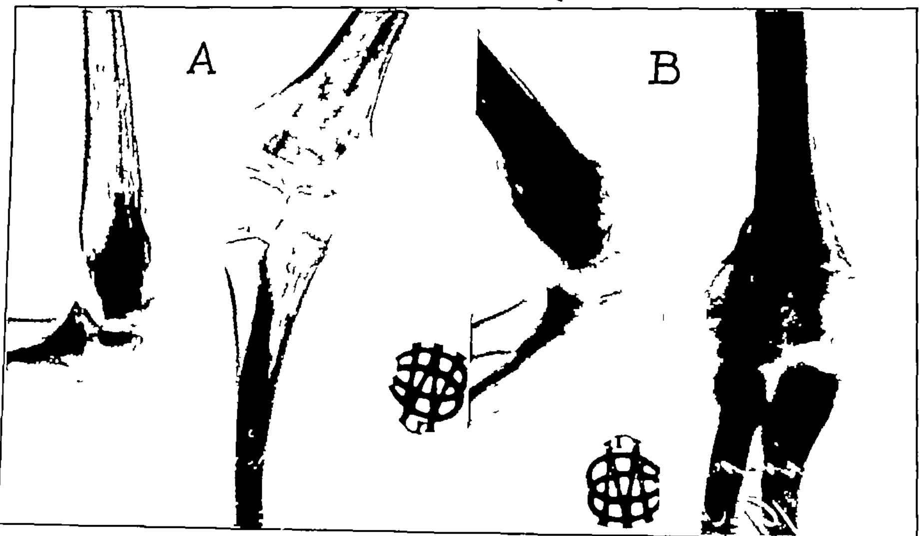


Fig. 412.—A Old supracondylar fracture of humerus with extreme varus deformity of elbow B Normal carrying angle restored after plastic osteotomy

angulation, rotation and lateral displacement (b) loss or increase of the carrying angle, (c) anterior displacement of the distal fragment with or without angulation.

The epiphyses are not directly involved in supracondylar fractures and growth disturbances are therefore less likely than in other fractures about the elbow joint. As growth will compensate for a moderate degree of deformity in young children, operative procedures are not warranted unless displacement and angulation are extreme.

Following reduction of the original fracture, especially if the distal fragment is displaced posteriorly, function and contour of the elbow may be fairly satisfactory except for limitation of flexion by a bony mass formed by the distal fragment. Usually in children, this mass will eventually be absorbed and a satisfactory range of motion restored, as demonstrated by Sever In adults, removal of the mass may incite even greater callus formation. For these reasons at least one year should elapse following the fracture before an attempt is made to remove the mass even then, in adults, the wisdom of the procedure may be questionable.

Malunion With Posterior Displacement

Malunited supracondylar fractures with posterior displacement and angulation of the lower fragment must be treated by surgical refracture and alignment of the fragments. Considerable dissection is required for mobilization and accurate approximation of the fragments.

Technic.—Two longitudinal incisions, one on the lateral, the other on the medial aspect, are made over the lower extremity of the humerus. By a careful study of the roentgenograms, usually the line of the old fracture can be determined Holes are drilled in line with the fracture site and the malunion broken up with an osteotome. The ends of the fragments are denuded of excess bone or callus, forming two surfaces for satisfactory apposition. After the fragments have been properly apposed and the normal alignment and position restored, a 1 6 mm. rustless steel nail is inserted in an upward and medial direction through the external condyle of the humerus, across the fracture site into the shaft. A similar nail is driven through the internal condyle in an upward and outward direction. Prior to closure of the wound, a two-view roentgenogram should be made to verify the correct position of the fragments.

After Treatment.—The arm is placed in a posterior right-angle splint. As soon as union is sufficiently solid, which usually is three weeks in children and four to six weeks in adults, active and passive motion and physical therapy are begun.

Malunion With Loss or Increase of the Carrying Angle

A moderate cubitus valgus or varus deformity of the elbow following supracondylar fracture may not be inconsistent with a serviceable degree of function. If the deformity is disabling however, or if there is an associated ulnar neuritis, correction is warranted. Correction is secured as described above, by refracture and realignment an additional amount of bone is removed from the lateral or medial supracondylar region to permit restoration of the normal carrying angle (Fig 412)

Malunion With Anterior Displacement and Angulation

Anterior displacement and angulation of the lower fragment is relatively uncommon. Motion usually is limited chiefly in extension The operative procedure consists of refracture reduction, and maintenance of the position by internal fixation as described above

UPPER THIRD OF THE RADIUS AND ULNA

Malunited fractures of the upper third of the bones of the forearm may be classified as follows (1) fractures of the head of the radius, (2) fractures of the olecranon, (3) fractures of the upper third of the ulna with anterior dislocation of the head of the radius (Monteggia fracture)

Malunion of the Head of the Radius

A mild degree of malunion of this fracture may produce no disability If a slight amount of excess bone is present resection of the excrescence may suffice to relieve symptoms. In severe deformity pronation and supination may be limited and accompanied by pain. Occasionally, flexion or extension of the elbow is likewise limited These findings may also follow malunion of fractures in the region of the bicipital tubercle If disability is extreme, ex cision of the head of the radius, as described for fresh fractures of this region (p 494) is necessary All loose fragments, excess bone scar tissue and periosteum and the remains of the orbicular ligament should be meticulously resected in an endeavor to prevent formation of new bone at the fracture site. Physical therapy is begun as soon as the wound has healed

In a small number of cases, this treatment may result in perfect function frequently, however the outcome is disappointing and no absolute assurance should be given the patient that function will be restored.

Malunion of the Olecranon

Function may often be materially improved following malunion of frac tures of the olecranon by excision of the offending portion. It has been proved repeatedly that one can dispense with a major portion of the olecranon. Refrac ture and realignment should not be attempted as such a procedure is likely to be followed by an increase in disability

Malunion of the Upper Third of the Ulna With Anterior Dislocation of the Head of the Radius (Monteggia Fracture)

In malunion of this fracture, the deformity is frequently so disabling that any measure is worthy of trial. Unfortunately, after the lapse of a year or more, the reaction in the humeroulnar articulation will have become so exten sive that restoration of even an approximately normal elbow joint may be im possible.

Technic.—Exposure of both the head of the radius and the fracture of the ulna is provided by a single incision (p 187) or two incisions may be em ployed as follows Through a posterolateral incision (p 183) two inches in length the head of the dislocated radius is dissected loose from all attach ments. By means of a Gigli saw, the head, with the periosteum intact, is severed just above the level of the bicipital tuberosity and removed A second



Fig. 413.—*A* Old malunited fracture of shaft of ulna with dislocation of head of radius (Monteggia fracture). *B* Malunion of ulna broken up and fragments maintained in position by Vitallium plate. Head of radius excised. Excellent range of motion, both as to flexion of lbow and supination and pronation.

incision three inches in length is now made over the posterior aspect of the ulna and the bone is refractured as near the original site as possible The fragments are aligned in normal position and held by an onlay autogenous bone graft from the tibia

After Treatment.—If union is adequate at the end of six weeks measures are instituted to induce function.

Synostosis Between the Radius and Ulna

Synostosis or osseous union between the radius and ulna at the proximal radioulnar joint may follow severely comminuted fractures in this region The

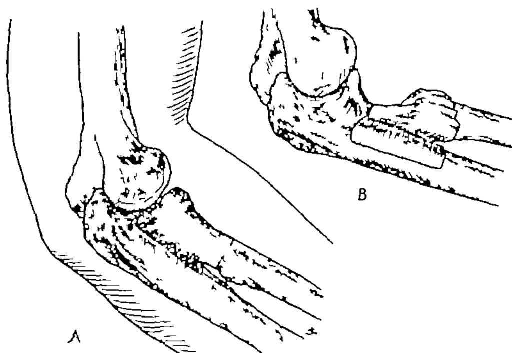


Fig. 414.—Operation for synostosis of radius and ulna *A* Shaded area shows amount of bone to be resected. *B* Fascia lata interposed between ulna and resected radius.

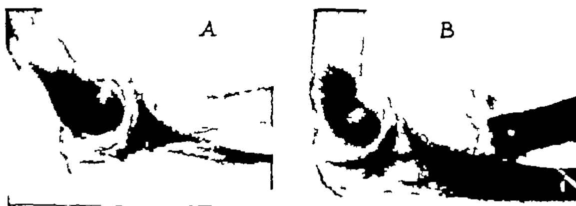


Fig. 415.—*A* Malunited fracture of head of radius with synostosis, of four months duration. *B* Synostosis recurred after resection.

surgical treatment consists of resection of a substantial segment of the radius with interposition of fascia lata between the resected end of the radius and the shaft of the ulna

Synostosis between the distal ends of the radius and ulna is treated by a Darrach's resection (p 597)

Technic.—The radioulnar joint and the proximal portion of the shaft of the radius are exposed by a posterolateral approach (p 183) With a chisel the bony union between the radius and ulna is broken up and the *proximal one* inch of the radius resected, i e., that part proximal to the bicipital tubercle. A double layer of fascia lata is placed between the shaft of the ulna and the resected end of the radius.

After Treatment.—As soon as the wound has healed, physical therapy should be instituted and continued over a long period of time

The end result is considered excellent if 50 per cent of the normal range of supination and pronation is obtained. Recurrence of synostosis is not uncommon.

SHAFTS OF THE RADIUS AND ULNA

Malunion of the Shafts of the Radius and Ulna in Children

Disability from malunion of the shafts of the ulna and radius in children may often be overcome by growth Surgery is indicated however if deformity is severe and overlapping of the fragments excessive.

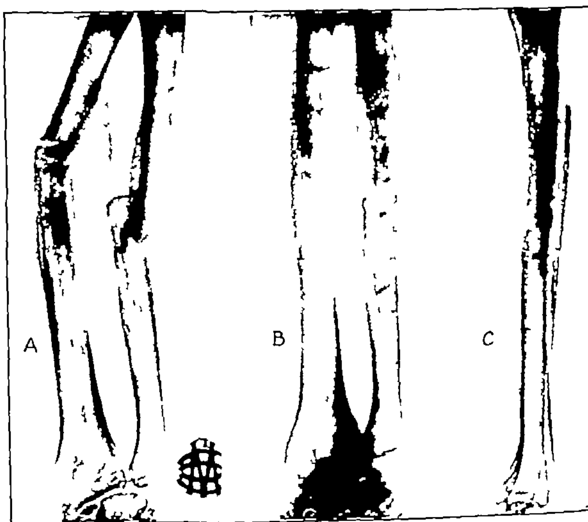


Fig. 416.—*A* Malunion of shaft of radius, with nonunion of fracture of shaft of ulna. *B* and *C*, Alignment restored by osteotomy of radius. Fixation and osteogenesis by onlay bone grafts.

Technic.—If the fragments are in good apposition and the deformity consists of angulation alone or lateral and a medial longitudinal incision (p 182), each two inches in length will expose the fracture site of both bones. With a one half inch osteotome the bone is severed and the angulation corrected.

Extreme overlapping and displacement of the fragments necessitates a wider exposure The technic is similar to that described below for adults, although internal fixation is not, as a rule required

After Treatment.—With the elbow held at a right angle and the forearm in mid position, a cast is applied from the axilla to the heads of the metacarpal bones. The cast is bivalved to allow for swelling A roentgenogram should be made immediately to check the position of the fragments. The treatment thereafter is carried out as described for fresh fractures of the forearm precautions being taken to prevent posterior bowing

Malunion of the Shafts of the Radius and Ulna in Adults

Under no circumstances should an extensive operation be performed for malunited fractures of both bones of the forearm in adults unless angulation and overlapping are pronounced and disability is extreme, as nonunion of one or both fractures is not uncommon. Further when overlapping is excessive, of necessity there must be considerable stripping of the periosteum and a fair measure of surgical trauma to obtain end to-end apposition of the bones.

Seldom is an osteotomy for restoration of good alignment advisable without some form of internal fixation. An onlay bone graft is most desirable, thus, not only is fixation complete, but an osteogenic factor is added.

Technic.—Two longitudinal incisions four to six inches in length one on the lateral and the other on the medial aspect, expose the fracture sites. The periosteum is disturbed as little as possible. With a 2 mm drill, union between the overlapping and angulated fragments is outlined and the fragments severed. If malunion is of long duration and overlapping excessive resection of one fourth to one half inch of the ends of the bones may be necessary Since shortening is less disabling than in a weight bearing extremity, sufficient bone may be resected to prevent buckling from tension of the soft structures yet permit firm apposition. The medullary cavity is reamed out and the fragments placed in normal alignment. In children or very young adults, the procedure may end here and the treatment proceed as for fresh fractures. In adults, fixation with an onlay graft or plate is desirable (p 374)

After Treatment.—A cast is applied from the axilla to the palm, immobilizing the elbow at a right angle and the forearm in mid position. The cast is bivalved to allow for swelling After two weeks the cast is removed and the alignment examined by inspection and by roentgenograms. The arm is then placed in a new snugly fitting cast, with little padding except over bony prominences. At eight weeks postoperatively union may be sufficiently solid to permit the use of a leather lacer brace with a drop ring catch at the elbow The joint should be held rigid for two or three weeks motion may then be allowed while fixation of the fracture site is maintained. Usually after three months union is sufficiently solid to dispense with the upper portion of the brace, and the arm may be removed from the remaining portion of the brace at intervals during the day for the purpose of exercise and physical therapy

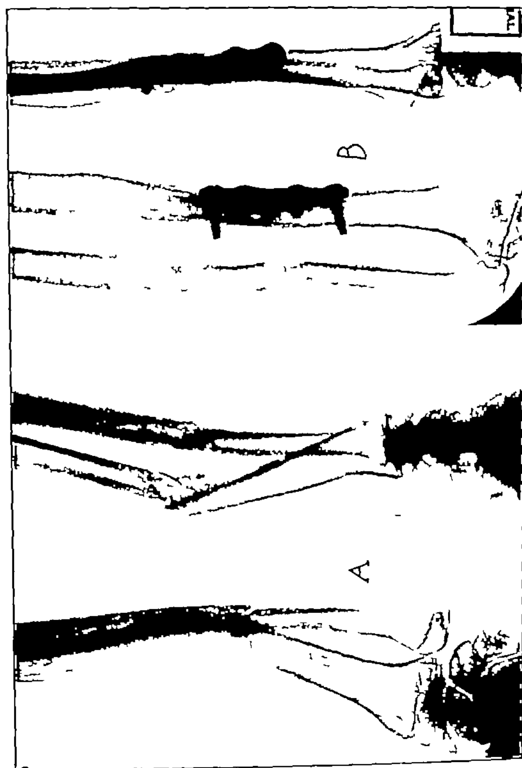


Fig. 417.—*A* Malunion of fracture of radius in a child. *B* Normal function after osteotomy and fixation with a metal plate.

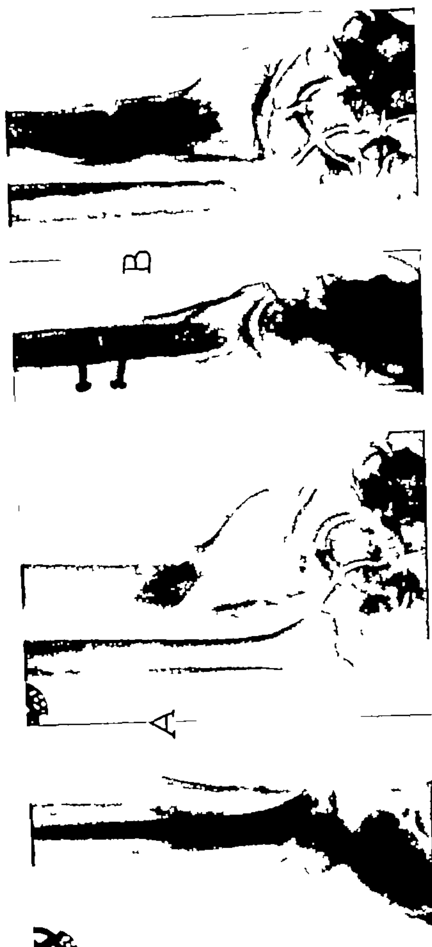


Fig. 418.—*A* Malunited fracture of distal end of radius. *B* Open reduction and internal fixation with onlay graft. Disproportion in length of bones necessitated resection of distal end of ulna.

Malunion at the Middle and Lower Thirds of the Radius

Fractures of this region often result in malunion with severe anterior bowing which produces gross irregularity at the wrist from radial shortening and a disability similar to that of malunited Colles fracture

Technic.—The skin and fascia are incised for a distance of three inches over the fracture site on the lateral aspect of the forearm the line of fracture is separated by osteotomy, and the angulation corrected. As maintenance of anatomic alignment is almost impossible by external fixation, internal fixation, either by an onlay bone graft three inches in length (p 654), or a small Vitallium plate, is advisable, wire loops are of little value in preserving alignment

After Treatment.—With the forearm and wrist in neutral position, a cast is applied from the metacarpophalangeal joints to the upper third of the arm. Postoperative measures are then carried out as for fresh fractures of this region protection, however is continued for a longer period of time.

Malunion of the Shaft of the Ulna

Operation for uncomplicated malunited fractures of the shaft of the ulna alone is so seldom necessary as hardly to deserve mention. Correction may *be accomplished, however by the principles described for fractures of the* shaft of the radius.

MALUNITED COLLES FRACTURE

Malunion occurs more often following Colles' fractures than any other *and is accompanied by considerable disability The deformity is* particularly unsightly in women. Malunion may be attributed to several causes

1. Failure to secure accurate reduction

2. Recurrence of the deformity after apparent reduction and confirmation *by the* roentgenogram

3 Excessive comminution. Although accurate reduction is accomplished and after treatment is most efficient, a certain number of comminuted fractures will unite in a moderate degree of malposition This is especially true if the articular surface of the radius is excessively comminuted.

4. Complete rupture of the radio-ulnar ligaments with undue mobility of the lower extremity of the ulna.

5 The institution of active motion and physical therapy before consolidation of the fracture is complete.

6 Excessive compression. In elderly individuals with senile osteoporosis of the bones of the wrist, the distal end of the radius may be crushed to such a degree that, even after disimpaction of the fragments, some residual radial shortening with broadening of the wrist, will persist.

Sudeck s atrophy or acute, painful osteoporosis, is a distressing complication which often follows malunion of fractures about the wrist. In the early stages, this entity is characterized by an extreme swelling of the soft tissues, exquisite tenderness on pressure, and pain on motion. With the passage of time, definite circulatory changes take place in the soft tissues and bone. The skin gradually assumes a purplish color is cold and perspires excessively As the pathologic process continues, *the finger joints and the* wrist become increas



Fig. 410.—Malunited Colles' fracture treated by simple osteotomy and resection of distal end of ulna.

ingly stiff Even the shoulder and elbow may be affected secondarily from voluntary immobilization of the extremity in one position *Roentgenograms reveal* a mottled decalcification of the bones.

Prior to surgery, combative measures must be undertaken No form of therapy is entirely satisfactory, minimum immobilization with active and passive exercises, and occupational and physical therapy seem to be as effective as any method. Mumford feels that roentgenotherapy is a rational form of treatment to relieve pain and muscle spasm Until symptoms and findings are relatively static or some definite improvement is apparent surgery should be delayed

Because of the wide variation in extent of the deformity differentiation must be made between the border line cases, in which physical therapy will give serviceable wrists, and those wherein surgery is expedient.

After the elapse of two weeks or more following the fresh fracture, the use of manipulation alone to improve the position of the fragments is not wise. This is particularly true if the patient is elderly and osteoporosis is present, in that manipulations may further comminute the fragments and fail to break up the impaction.

In 1945, Speed and Knight studied sixty cases of malunited Colles' fractures wherein surgery had been employed This study revealed that no one type *of corrective operation was applicable to all cases. The procedures vary* considerably according to the type of deformity and the degree of displacement. In the majority of cases, surgery offers an excellent prospect of improving the appearance and function of the wrist

Operative measures employed in the correction of malunited Colles fractures are of four general types

1. Procedures designed to restore normal anatomic relationships, i.e., reestablish the normal angle of the articular surface, correct radial shortening and reduce the prominence of the distal end of the ulna. Simple osteotomy of the radius the Campbell or Speed reconstruction, and dual or single onlay bone grafts are examples of this group

2. Compensatory procedures to improve function, as Darrach's resection of the ulna.

3 Arthrodesis

4. Combinations of the above procedures, such as arthrodesis combined with Darrach's resection of the distal end of the ulna.

Prior to operation, the possible necessity for an arthrodesis should be explained to patients with severe malunion as one cannot always determine before operation whether reconstruction should be attempted, or whether a wrist fusion *is more appropriate.*

Although improvement of function is the primary consideration in the treatment of malunited Colles' fractures, surgical objectives should also include an improvement in the cosmetic appearance of the wrist.

Surgical Approaches to the Distal End of the Radius and Ulna

The following exposures of the distal end of the radius and ulna are relatively common to all operations. Previously the radial or lateral approach *to* the distal end of the radius was employed for the Campbell reconstruction procedure. This procedure is best carried out through the dorsal approach described

below The latter provides a more satisfactory exposure, and a more complete and direct view of the fracture

Exposure of the Distal End of the Radius—A longitudinal incision is made through the deep fascia beginning at Lister's tubercle (dorsal radial tubercle), and extending proximally two or three inches. The incision should be of adequate length as a short exposure, even though more satisfactory cosmetically entails more vigorous retraction during the operation and thus a greater local postoperative reaction Dissection is carried down to the bone between the extensors carpi radialis longus and brevis and the extensor pollicis longus laterally, and the extensor digitorum communis medially Care is taken to avoid injury to the tendons, and to expose the bone subperiosteally

Exposure of the Distal End of the Ulna.—The incision begins at the tip of the ulnar styloid process and extends along the medial aspect of the forearm two inches Dissection is carried down between the extensor and flexor carpi ulnaris tendons, the dorsal cutaneous branch of the ulnar nerve being avoided

Osteotomy

Simple osteotomy is applicable to a limited group of malunited Colles' fractures, chiefly those wherein the deformity consists largely of dorsal tilting of the distal articular surface of the radius, with little or no radial shortening and with no appreciable involvement of the distal radio-ulnar joint. The technic consists of division of the bone through the line of the old fracture, and re-establishment of the normal angle of the articular surface. Internal fixation is unnecessary

This procedure does not correct any abnormality in the relationship of the distal radio-ulnar joint, nor does it take into consideration any shortening of the radius, or broadening of the wrist In the presence of these disturbances, the method is inadequate.

In our series of cases 23 operations of this type were performed, with satisfactory results in the majority though approximately 20 per cent of the patients had a partial recurrence of the deformity during the period of immobilization In most cases, the recurrent deformity was not of sufficient degree to impair the final result. In a few cases, in addition to the radial osteotomy the prominence of the medial portion of the ulnar head was removed for cosmetic reasons.

The technic of this procedure requires no special description (see below)

Osteotomy and Bone Graft

Inclan Bennett, Durman, Ghormley and others have performed an osteotomy of the radius to correct malunited Colles' fractures and have maintained correction by means of a wedge-shaped graft Inclan and Bennett removed the graft from the tibia Durman, from the proximal fragment of the radius. Inclan utilized a preliminary osteotomy of the ulna The Campbell technic differs slightly from these methods in the manner of obtaining the graft, and in the correction of the undue prominence of the ulna and broadening of the wrist Following osteotomy of the radius through the fracture site and correction of the backward angulation of the distal fragment the graft is removed from the distal end of the ulna and utilized to maintain correction of the radius. Excision of the graft from the ulna reduces the abnormal prominence of this bone and the broadening of the wrist. Improvement from a cosmetic standpoint has

been satisfactory though radial length has not always been completely restored by this procedure The Campbell operation is applicable only to those deformities with minimal shortening

Technic (Campbell) —A lateral incision two inches in length is made over the lower extremity of the radius and carried subcutaneously between the

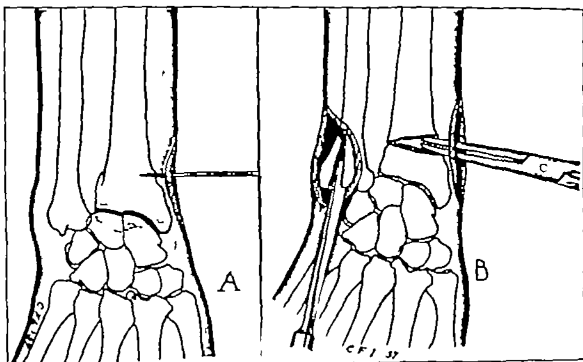


Fig. 420—Operation for malunited Colles' fracture (Campbell) *A* Osteotomy through fracture site backward angulation corrected. *B* Radial length restored. Graft removed from prominent distal end of ulna, through separate incision.

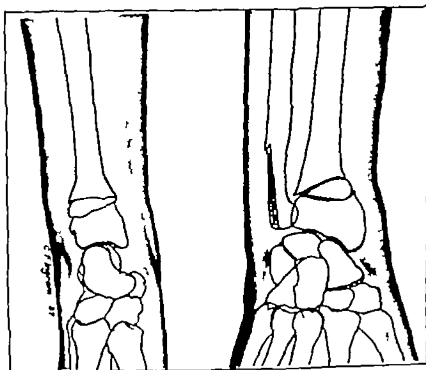


Fig. 421.—Same as Fig. 420. Restoration of normal radial length and normal angle of articular surface after insertion of two-dimensional wedge-shaped graft from ulna into osteotomy site.

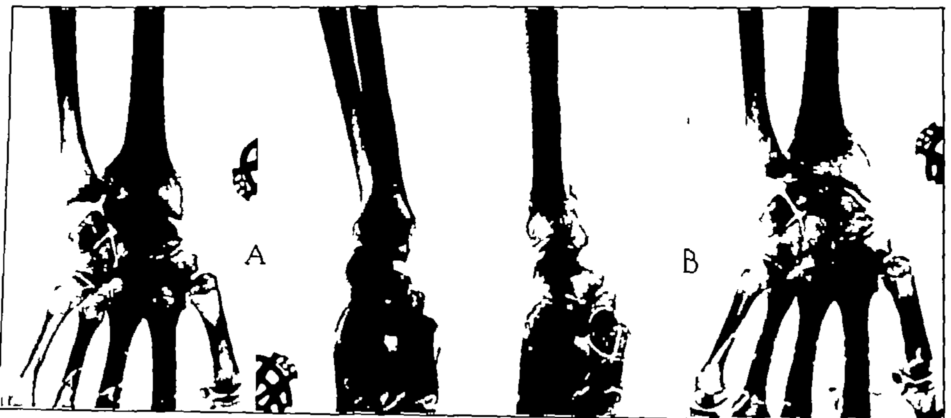


Fig 422.—A Malunited Colles' fracture with marked radial shortening and backward angulation. B After Campbell plastic operation normal angulation and radial length.

brachioradialis and the abductor pollicis longus and extensor pollicis brevis muscles to the line of fracture The radius is severed by a transverse osteotomy three fourths to one inch proximal to the articular surface. The posterior angulation of the lower fragment may then be corrected by acute flexion of the wrist joint, the lower fragment being angulated slightly downward and forward. A hemostat may be inserted between the fragments and opened with moderate force thus separating the fractured surfaces and demonstrating the amount of radial length which may be restored. This wound is closed temporarily

The lower extremity of the ulna is approached through a medial incision two inches in length. The periosteum is incised and stripped from the inner half of the ulna from above downward exposing the articular surface and the styloid process. With a small osteotome, the inner half or third of the head and the inner portion of the shaft are severed from below upward a free graft of bone one inch in length and one half inch in thickness at one extremity and tapered at the other being thus obtained. The triangular ligament, if ruptured or detached from the ulna may be replaced by means of a suture inserted through a drill hole.

The graft is now trimmed with bone forceps into a pyramidal wedge with a base on both the dorsal and lateral aspects, and is inserted into the space between the fragments of the radius. The dorsal side maintains the normal angle, while the lateral side prevents recurrence of radial shortening. The lower fragment should be slightly over reduced by anterior angulation. On inspection, the head of the ulna may be less prominent than in the normal wrist otherwise the external contour should be approximately normal The lateral dimension or width of the wrist joint should be normal, and on palpation the styloid process of the radius should be distal to the lower end of the ulna.

After Treatment.—A sterile Canton flannel bandage is applied from the metacarpophalangeal joints to just above the elbow, and the arm is placed in a sugar tong cast or molded plaster anterior and posterior splint. While this is consolidating the forearm is held in mid position, the wrist is *slightly flexed* to place the posterior capsule under tension, and pressure is exerted over the dorsum of the wrist to maintain the distal fragment of the radius in proper relation.

The roentgenogram should demonstrate practically normal alignment, the lateral view will show that the normal plane of the lower articular surface of the radius has been restored, and the anteroposterior view will show that the styloid process of the radius is one half inch distal to the lower extremity of the ulna, the styloid process of the ulna having been excised. Further roentgenograms should be made through the plaster splint at the end of one week, and again after two weeks, to check the position of the bones. Any slight recurrence of deformity is then corrected. The plaster splint is removed one month postoperatively roentgenograms are made, a small anterior metal splint with straps and buckles is applied and active and passive exercises and physical therapy are begun

Osteotomy and Intramedullary Bone Graft

The most practical means of maintaining the length of the distal fragment is by the use of an autogenous or homogenous (bone bank) intramedullary bone graft. An intact or at least a satisfactory radial articular surface is an essential

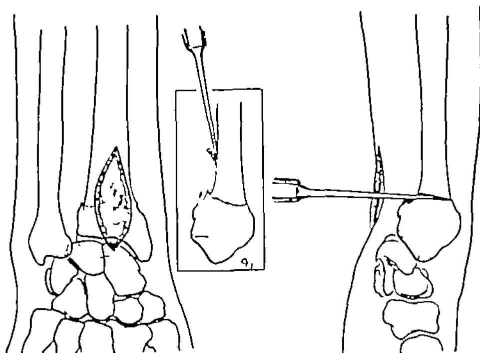


Fig 423.—Osteotomy and intramedullary bone graft for malunited Colles fracture (J S. Speed) Fracture exposed through d rsal incision. Exact line of fracture identified by peeling callus from dorsal surface of radius, beginning proximally and proceeding distally Radius divided with an osteotome

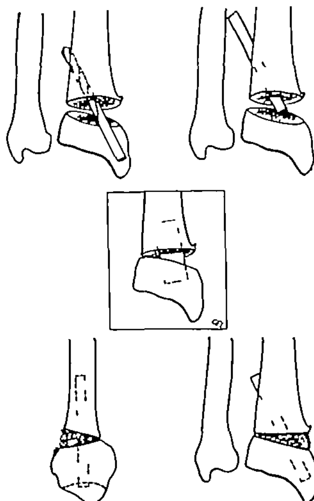


Fig 424.—Same as Fig. 423 Hole drilled into medullary cavity of proximal fragment, and thence through ulnar aspect of radial cortex. Intramedullary bone peg inserted retrograde for sufficient distance to permit reduction of fracture. Subsequently, intramedullary graft tapped across osteotomy site and into the distal fragment. Defect filled with cancellous bone Insert shows alternate method of utilizing larger graft.



Fig 426 —*A* Malunited reverse Colles' fracture with marked radial shortening and anterior displacement of distal fragment. *B* Normal length and alignment restored after insertion of intramedullary graft.

requisite In the presence of extensive osteoporosis of the distal radial fragment, the use of the bone peg as internal fixation has proved the only practical means of maintaining the correction of the deformity The bone peg serves as an internal strut which supports the radial aspect of the distal fragment thus maintaining length In addition recurrence of the dorsal angulation of the radial articular surface is prevented during the period of consolidation The cuneiform defect created by the corrected position is filled with cancellous bone. If indicated, the lower end of the ulna may be resected, and the excised portion of the ulna employed as a graft at the site of the radial osteotomy, thereby still further stabilizing the radial fixation

This procedure is also applicable to fresh and malunited reversed Colles fractures, and to fractures of the radial styloid process with dorsal subluxation of the wrist joint.

Technic (J S Speed).—The dorsal surface of the radius is exposed as described above Because of a thick bridge of callus, the exact line of the fracture is not easily identified. With an osteotome the callus is peeled off the dorsal surface of the radius, beginning proximally and proceeding distally until the end of the cortex at the fracture is exposed. The radius is severed by a vertical transverse osteotomy through the line of the fracture Severance with a periosteal elevator or osteotome at this stage will succeed only in crushing and tearing up the soft, osteoporotic fragments. Considerable dissection and loosening up ' must be first carried out The osteotomy site is gently opened by simultaneously lifting the shaft fragment and angulating the distal fragment.

The ulnar aspect of the radius is exposed subperiosteally With the wrist flexed, the distal end of the proximal fragment is brought up slightly out of the wound. A $\frac{3}{16}$-inch drill is then introduced into the intramedullary cavity of the proximal radial fragment and a hole is drilled obliquely through the ulnar aspect of the radial cortex. The drill point should emerge one to one-half inch proximal to the osteotomy site A small homogenous or autogenous bone peg (about $\frac{1}{8} \times \frac{3}{16} \times 1\frac{3}{4}$ to 2 inches) is inserted obliquely through the osteotomy site and out through the hole in the radial shaft for a sufficient distance to permit reduction of the radial fracture With the distal fragment in proper alignment and position, the bone peg is tapped back across the osteotomy site and thence into the distal fragment any excess of the proximal end of the peg is removed flush with the shaft of the radius The residual defect at the osteotomy site is filled with cancellous bone The bone bank obviates the necessity of additional surgery to obtain the bone peg and the cancellous grafts

After Treatment.—See above

Single Onlay Graft—Dual Onlay Graft

These procedures are seldom applicable to ordinary malunited Colles fractures. In one case in this series, internal fixation by means of an intramedullary peg did not maintain a stable correction of the deformity In this case the procedure was supplemented by the use of a small fragment of the ulna as a dorsal onlay graft, the graft being fixed by two Vitallium screws.

The dual graft is primarily applicable to nonunion of a Colles' fracture (p 727) with loss of bone substance. Because of the forcepslike effect of the dual graft, it is possible to grasp the distal osteoporotic fragments in a stable manner and provide a trough for the cancellous bone which fills in the defect.

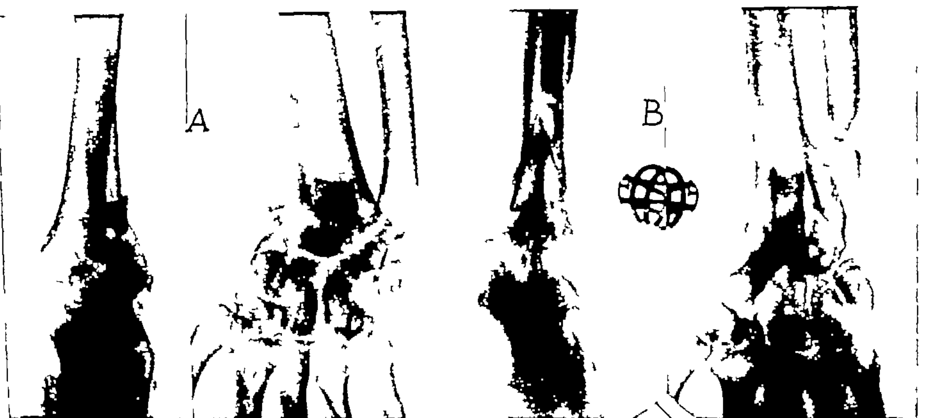


Fig. 426.—*A*. Comminuted Colles' fracture of left wrist of one month's duration. *B*, Eight months after arthrodesis of radius to scaphoid and semilunar bones. Intercarpal motion preserved.



Fig. 4 —A Comminuted fracture of right wrist (same patient as Fig. 426) B Articular surface of radius reconstructed and held in position by fine, stainless steel wire.

Resection of the Distal End of the Ulna

Resection of the ulna does not restore the normal mechanics *or contour of* the wrist but is entirely compensatory, being based upon the tenet that the disability, i. e., pain, limitation of rotation, and deformity arises chiefly *from the* distal radio-ulnar articulation. If the reduction of the radial fracture is satisfactory and the traumatic arthritis of the radio-ulnar joint is the major source of disability resection of the distal end of the ulna (p 597) will suffice. This is a simpler procedure, the postoperative disability is slight and of short duration, and the end result definitely satisfactory For the ordinary malunited Colles fracture, the ulna frequently is resected as a supplement to one of the methods described above and below

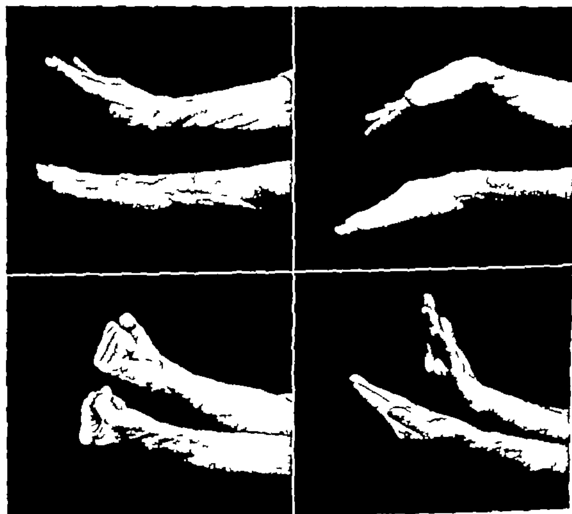


Fig. 428.—Same patient as Figs. 426 and 427 Patient has two serviceable wrists with relatively little disability considering magnitude of injuries. A little flexion and extension remain in intercarpal joints of left wrist, despite fusion of radiocarpal joint.

In 1944 Boyd and Stone studied the results of resection of the distal end of the ulna. There were 22 resections, two of which were bilateral, performed by various members of the staff at Campbell Clinic. In no case did resection of the lower end of the ulna increase the disability of the wrist. In all those wherein radial shortening was present, the cosmetic appearance of the wrist was improved. In those wherein no radial shortening was present, the absence of the head of the ulna was more noticeable, as no deformity was present before the

operation The absence of the head of the ulna altered the appearance of the wrist, but this was of little cosmetic importance The muscle power in the wrist and the grip in the hand were slightly diminished, though to a much less degree than one would expect Motion in the wrist, particularly pronation, supination ulnar deviation and in some cases, dorsiflexion, was improved

Arthrodesis

All of the procedures described for malunited Colles' fractures are designed to preserve motion in the wrist, and pronation and supination of the forearm If the fracture is situated close to the articular surface, and is complicated by marked osteoporosis or severe comminution of the distal radial fragment, a satisfactory movable wrist cannot be obtained, and arthrodesis or fusion is the logical solution to the problem Because of the associated radio-ulnar disproportion in length, and the traumatic arthritis of the distal radio-ulnar joint, resection of the distal end of the ulna is usually combined with arthrodesis

Mere intra-articular arthrodesis of the proximal row of carpal bones to the radius is inadequate. This is usually only the first step in an arthrodesis which includes a substantial graft extending from the dorsum of the carpus proximally onto the dorsal surface of the radius. The technics of arthrodesis are described in Chapter XV

Malunion of Reversed Colles Fracture (Smith's Fracture)

In reversed Colles' fractures, or union with the distal fragment of the radius in slight flexion, the deformity may be commensurate with good function. Surgery is indicated only when the distal fragment is united in extreme flexion and motion is materially limited. The principles of correction are similar to those employed in malunited Colles fractures, differing only in that the lower extremity must be replaced posteriorly instead of anteriorly to restore the normal plane of the wrist joint The intramedullary bone graft procedure (p 587) is particularly appropriate.

Derangement of the Distal Radio-ulnar Joint

Many of the entities responsible for derangement of the distal radio-ulnar joint will be considered herein Since malunited Colles fracture is the most common offender the entire discussion is placed here to avoid repetition in other sections of the text.

The distal radio-ulnar joint functions primarily to stabilize pronatory and supinatory movements of the forearm the radius rotating on the distal end of the ulna. Except for the ulnar side, the head of the ulna is completely covered with articular cartilage to coincide with the sigmoid cavity of the radius. The integrity of this articulation is maintained by the ulnar collateral ligament, which extends distally from the tip of the styloid process of the ulna, and by the triangular fibrocartilage, which attaches to the base of the styloid process and to the margin of the sigmoid cavity of the radius. Further stability is added by the anterior and posterior radio-ulnar ligaments, and by the action of the pronator quadratus muscle Disability in this joint consists of pain, limitation of pronation and supination, weakness of grip, and, frequently deformity The last is usually manifested by a dorsal prominence of the distal end of the ulna. In the presence of a disproportion or relative increase in length of the ulna over the radius, the hand and wrist will be maintained in a position of radial deviation

Darrach and Milch have been particularly interested in derangement of the distal radio-ulnar joint. We have drawn heavily from their experience in the preparation of the subsequent section.

Disability at the radio-ulnar joint may be classified as follows

1 Laxity subluxation or dislocation secondary to rupture of ligamentous structures.

2 Derangement of the joint secondary to malalignment, angulation or disproportion in length of the radius and ulna.

3 Arthritis secondary to trauma, congenital abnormalities, or other causes.

The surgical treatment of derangements of the distal radio-ulnar joint will be considered in the light of the above classifications.

Repair of the Ligamentous Structures

Rupture of the ligamentous structures about the distal radio-ulnar joint or an isolated fracture of the styloid process of the ulna may allow laxity of the joint, associated with recurrent subluxation or a dislocation. Moderate laxity of this joint is not incompatible with satisfactory function, particularly if the occupation of the patient does not necessitate forceful supination and pronation of the forearm Repair or reconstruction of the ligaments is indicated in the presence of extreme laxity of the distal radio-ulnar joint or a persistent dislocation of the joint of less than six weeks' duration Subluxation or dislocation of longer duration is usually accompanied by well-developed arthritic changes, incident to the trauma. Operations upon the soft tissue may stabilize the joint but will not eliminate the arthritic changes. Limitation of pronation and supination may follow as a result of fibrosis and arthritis as a consequence, the ulna will not rotate smoothly in the fascial loop Or on the other hand, soft tissue stabilization may not be adequate, allowing recurrence of the subluxation

Repair or reconstruction of the ligaments of the radio-ulnar joint is not indicated as a primary procedure in the presence of any malalignment angulation, or discrepancy in length of the two bones. Milch has particularly stressed the fact that bony relationships must be normal or must be re-established before any soft tissue operations are undertaken.

If one adheres to these indications and contraindications, the ligaments should be reconstructed in only a small group of cases. Preservation of this joint followed by residual pain, stiffness and rigidity is worse than the slight instability and weakness which may be associated with resection of the distal end of the ulna. We may make an exception to this rule in cases of young children Preservation of the distal ulnar epiphysis and the stability afforded by the distal end of the ulna is desirable. Further incongruity or differences in contour at the radio-ulnar joint will be better compensated for and produce *fewer symptoms than in adults.*

Milch in 1926 described an operation wherein a fascial strip was utilized not only to restore the action of the triangular ligament, but to reinforce either the anterior or posterior radio-ulnar ligaments.

Technic (Milch).—A one-inch incision is made along the medial border of the ulna one-half inch above the tip of the styloid process. The radius is exposed through a second longitudinal incision slightly medial to the groove for the abductor hallucis longus muscle By blunt dissection, a tunnel is created along the anterior surface of the pronator quadratus muscle beneath

all the flexor tendons, from the ulnar to the radial side of the wrist. In a similar manner, a dorsal tunnel is also made beneath the extensor tendons to the lateral surface of the radius. Guide sutures are passed through these tunnels. An incision is then made on the ventral surface of the wrist between the tendons of the flexor carpi radialis and flexor pollicis longus muscles at the level of the previous incisions. A hole is now drilled through the radius in a posterior and lateral direction and a guide suture is drawn through this hole from the radial incision. In a similar manner a dorsal incision is made over the radius between the tendons of the extensor pollicis longus and extensor communis digitorum muscles, a second hole is drilled through the radius in an anterior and lateral direction, and a guide suture passed through this hole from the radial incision

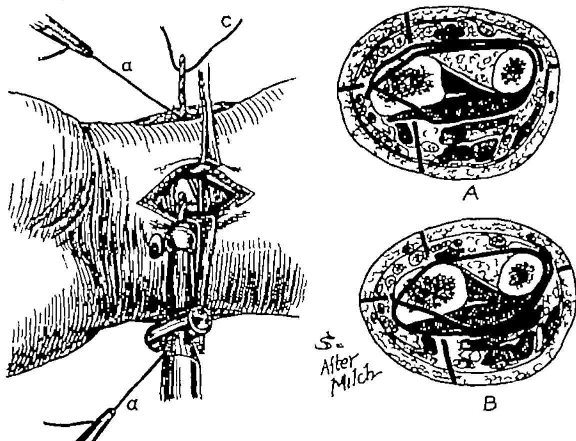


Fig. 429.—Operation for dislocation of distal radio-ulnar joint (technic, Milch) "Ventral incision showing pronator quadratus with guide suture a running across it and emerging at the radial and ulnar incisions. The bone drill emerging at the radial incision is being threaded with guide suture c. A Schematic drawing showing lines of incision and arrangement of fascial graft for posterior dislocation of ulna. B Schematic drawing showing lines of incision and arrangement of fascial graft for anterior dislocation of ulna." (Redrawn from Milch, Henry Am. J Surg. 1: 141 1926.)

A strip of fascia lata eight inches long and one inch wide is next removed from the outer aspect of the thigh and folded lengthwise on itself, the smooth gliding surface being turned outward. By means of a guide suture this strip is drawn through one of the channels in the radius, thence around the neck of the ulna, and out through the second channel at the radial incision. With the hand in mid pronation, the head of the ulna is approximated closely to the sigmoid cavity by the fascial band and the free ends of the sling are crossed and sutured.

If the dislocation of the ulna is posterior a new posterior radio-ulnar ligament is formed by passing the longer end of the fascial strip beneath the

extensor tendons to the ulnar incision. With the hand in extreme pronation, the end is sutured to the head of the ulna on a plane slightly distal to that of the newly made sling For anterior dislocation, the end of the strip is passed beneath the flexor tendons to the ulnar incision and sutured to the anterior surface of the head of the ulna, while the hand is held in extreme supination.

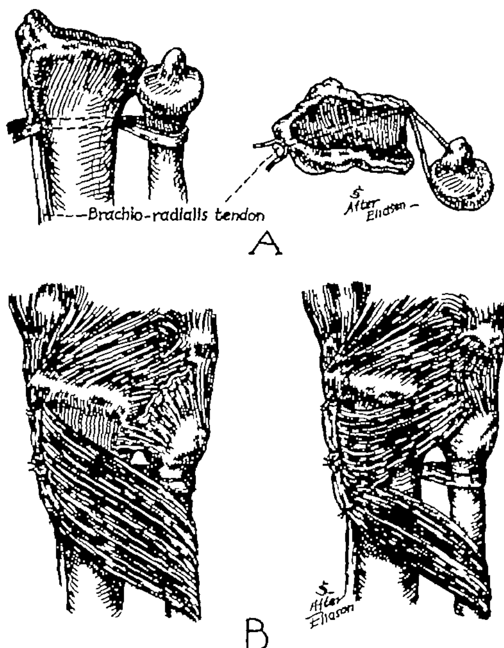


Fig. 430.—Eliason operation for dislocation of inferior radio-ulnar joint. *A*, Method of constructing artificial orbicular ligament to maintain distal end of ulna in close contact and proper relationship to radius. The two loose ends of fascia lata are passed through a drill hole in radius and sutured about the brachioradialis tendon. *B*, Plication of anterior ulnar ligament and transference of distal portion of pronator quadratus muscle. (Redrawn from Eliason, E. L. Ann. Surg. 96 27 1932.)

After Treatment.—The wrist and hand are immobilized in a cast for ten days to two weeks, or until healing is complete. Gentle passive and active exercises are then begun.

Although this is a rather extensive operation, the ligaments are restored completely

Eliason influenced by the Milch technic, utilized a simple sling of fascia to simulate the attachment and action of the triangular ligament. The two ends of the sling are passed transversely through a drill hole in the radius to the lateral side of the wrist. The anterior and posterior radio-ulnar ligaments are plicated.

Technic (Eliason) —The lower ends of the radius and ulna are approached through a lateral and medial incision, respectively Two loops of heavy silk are drawn around the ulna with an aneurysm needle and the ulna is dislocated forward The radius is now drilled in an oblique direction from its posterior and ulnar aspect forward and outward, the drill penetrating the outer radial cortex one and one-half inches above the styloid process A strip of fascia lata eight inches long and one and one-half inches wide is removed from the thigh and passed about the ulna, forming a sling The two ends of the strip are next inserted separately through the drill hole in the radius and drawn taut, bringing the ulna in proper relation with the radius The ends of the strip are then passed around the tendon of the brachioradialis muscle close to its insertion and fastened together with sutures. Through the ulnar incision, the anterior radio-ulnar ligament is incised and the edges are overlapped and plicated with interrupted chromic catgut sutures. To facilitate approximation between the two bones, the distal half of the ulnar attachment of the pronator quadratus muscle is detached from the ulna shifted distally, and sutured over the joint. The posterior radio-ulnar ligament is incised and plicated with chromic catgut sutures.

Technic (Lowman) —See Madelung's Deformity Chapter XXV

Correction of Malalignment, Angulation, or Disproportion in Length of the Radius and Ulna

Disturbances of the distal radio-ulnar joint incident to malalignment or angulation of the radius or ulna ordinarily cause little disability, if the primary deformity is corrected. In cases of long standing wherein marked arthritic changes of the radio-ulnar joint are present, resection of the distal end of the ulna (p 597) may be necessary

Protrusion of the head of the ulna beyond its normal articulation with the sigmoid cavity of the radius and consequent impingement upon the carpus may be caused by a variety of factors, three of the common ones being malunited Colles' fracture, malunited or ununited fractures of the radius, and cessation or abnormality of growth of the distal radial epiphysis. There are three possible modes of attack upon this problem (1) restoration of the length of the radius, (2) shortening of the ulna and (3) resection of the distal end of the ulna.

The relative merits of the various procedures applicable to malunited Colles' fractures, and their indications and contraindications are described above In ununited fractures of the radius or malunited fractures with overlapping of the fragments, not associated with fracture of the ulna, radial shortening produces a derangement or abnormal relationship of the articular surfaces of the radio-ulnar joint. If the shortening is pronounced the distal radio-ulnar joint may become dislocated secondarily In cases of long standing the soft tissue structures may contract to such an extent that the normal radial length cannot be restored at operation, even after thorough mobiliza

tion of the radial fragments Rather than attempt to bridge the defect in the radius and restore normal radial length, it is simpler to resect the distal end of the ulna and bone graft the shortened radius with the two fragments in apposition

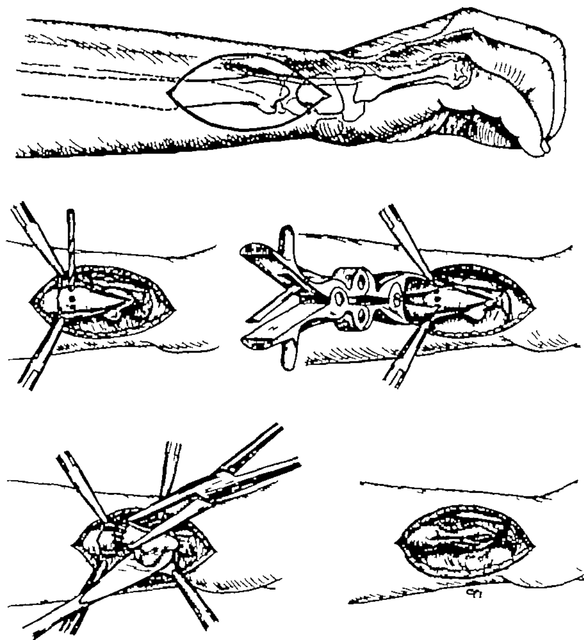


FIG. 431 —Resection of distal end of ulna. *A*, Exposure *B C*, Holes drilled through cortex of ulna to facilitate division with bone-biting forceps. This technic prevents crushing and fracturing of the bone. *D* Fragment turned out of wound to allow division of soft tissue structures. *E* Periosteal envelope and ligaments reefed and plicated to stabilize resected end of bone.

A similar problem arises in severe flexion contracture of the wrist, as in Volkmann's contracture, or in untreated rheumatoid arthritis. To correct the flexion deformity and arthrodese the wrist, partial resection of the carpus and the lower end of the radius is often necessary Shortening of the radius and carpus produces a discrepancy in ulnar length which requires resection of the lower end of the ulna Pronation and supination are possible following fusion of the radius to the carpus combined with this procedure.

Resection of the distal end of the ulna was first performed by Darrach at the suggestion of Dwight in 1910. The operation was originally employed for an old dislocation of the ulnar head, associated with a fracture of the distal end of the radius. Since that time, it has been used alone or in combination with other procedures for a variety of conditions.

Resection of the Distal End of the Ulna (Darrach).—The distal end of the ulna is exposed by a medial longitudinal incision (p. 187). The periosteum is reflected from the lower portion of the ulna with care to avoid intrusion upon the adjacent spaces. The bone is severed obliquely at a point approximately one inch from its distal end. The distal fragment is then turned outside the wound to allow division of the capsule close to the articular cartilage. The styloid is divided at its base, the ulnar collateral ligament being left attached. The latter, together with the periosteal envelope, provides a firm attachment which prevents laxity.

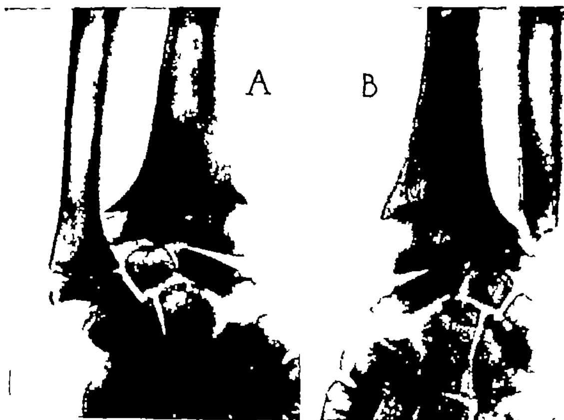


Fig. 432.—*A*, Disproportion in length of radius and ulna secondary to injury of distal radial epiphysis. *B*, After resection of distal end of ulna. Unless child is approaching end of growth period, cuff resection of Milch would be preferable.

After Treatment.—No immobilization is required. The patient is allowed to begin active exercises the day after operation.

Darrach has observed that the bone within the periosteal envelope usually regenerates in some measure, varying from a mild excrescence of bone on the lower end of the ulnar fragment to an almost complete union with the styloid process. The ulnar head is never re-established. As a rule, rotary movements are restored after a few weeks, and the pain and deformity are relieved.

With abnormality or cessation of growth of the distal radial epiphysis, the ulna is lengthened proportionately, perhaps impinging upon the carpus. In

growing children especially the stability afforded by the distal end of the ulna should be preserved. As an alternative to resection of the distal end of the ulna with the epiphysis Milch has described a cuff resection of the ulna, whereby the latter is shortened sufficiently to allow the head of the ulna to coincide with the sigmoid cavity of the radius. If prevention of further growth is desirable, the cuff resection may include the distal ulnar epiphysis. Ordinarily, the procedure is carried out one inch proximal to the head of the ulna, a segment of the shaft proportionate to the discrepancy in length of the two bones being resected.

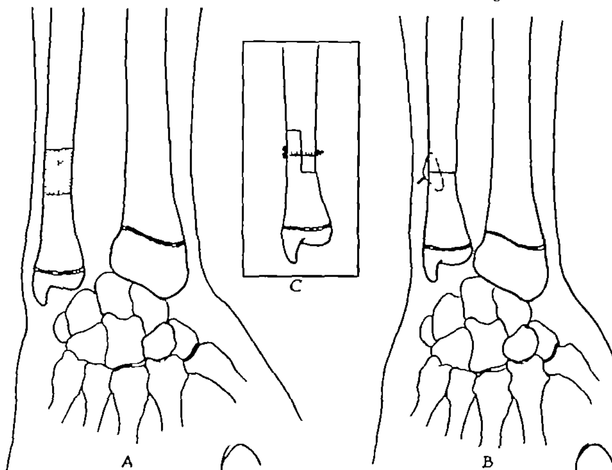


Fig. 433—Cuff resection of ulna (Milch) *A* Shaded area represents bone to be resected. *B*, Ends of ulna apposed, correcting disproportion in length of radius and ulna. *C* More stable fixation secured by step-cut procedure and fixation with one screw

Cuff Resection of the Ulna (Milch)—The distal end of the ulna is exposed by a two and one half to three inch incision on the medial aspect (p 187) With a Gigli s saw a segment of bone of appropriate length (three-fourths to one inch) is resected. The wrist is then placed in proper alignment and the ends of the fragments are apposed and fixed by a wire loop (In adults, particularly a little better fixation can be secured by step-cutting the bone and fixing the fragments with a screw)

After Treatment.—The forearm is immobilized in a sugar tong splint for three to four weeks at the end of that time union is usually solid, and active exercises may be instituted.

Arthritis

In arthritis of the radio-ulnar joint, pronation and supination are painful and usually restricted. These symptoms are accompanied by weakness in the grip If the pain and limitation of motion are sufficiently severe to handicap

the patient in his work, resection of the lower end of the ulna is indicated As the painful joint is removed, pain is relieved Pronation and supination are usually materially improved and may return to normal The weakness in the hand also improves.

In ankylosis of the distal radio-ulnar joint, pronation and supination are lost In order to restore these motions, an arthroplasty of the joint or resection of the lower end of the ulna is necessary The results of arthroplasty of this joint are usually unsatisfactory, resection is by far the simpler procedure, and the end results are better

In the correction of Madelung s deformity resection of the lower end of the ulna may be combined with an osteotomy of the lower end of the radius.

WRIST AND HAND

Malunion of the Carpal Bones

In malunited fractures of the carpal bones, surgery is not warranted merely for the restoration of anatomic alignment. Usually, the pathologic condition is either nonunion or dislocation (pp 696 304) In a few cases fusion of the wrist (Ch. XV) or excision of one or more carpal bones (p 698) may be required Approximately 50 per cent of normal motion may be restored by excision of these bones

Malunion of the Metacarpal Bones

Because of the difficulty of maintaining reduction, malunion of fractures of the metacarpal bones is comparatively common. The disability, however is seldom so severe as to necessitate surgery

Technic.—*The fracture line is approached through a dorsal longitudinal in* cision and the union is separated with an osteotome. The medullary cavity of each fragment is then reamed out with a small drill. A homogenous bone peg is inserted into the medulla of one fragment and the other fragment is reduced onto the protruding portion of the graft. If the neck of the bone is fractured, a small hole is drilled into the head from the fractured surface and the head of the bone is reduced onto the graft

After Treatment.—A malleable aluminum splint is applied from the tip of the finger well up the forearm Immobilization is continued for a period of three or four weeks.

MALUNION OF FRACTURE-DISLOCATION OF CARPOMETACARPAL JOINT OF THE THUMB (BENNETT S FRACTURE)

Malunited *fractures through the shaft of the first metacarpal* bone are seldom so disabling as to require surgical intervention. This is also true of fractures through the base of this bone which do not involve the carpometa carpal joint Fractures of the proximal articular surface of the metacarpal bone of the thumb however may be severely disabling particularly for a manual laborer In Bennett s fracture a small triangular segment of bone consisting of one-third to one half of the articular surface is separated from the shaft The posterior half of the articular surface together with the remainder of the metacarpal bone dislocates posteriorly If the treatment of the fresh fracture has been inefficient some degree of displacement remains and the gap between the two fragments is filled with fibrous tissue and callus.

In relatively recent cases, treatment consists of open reduction excision of the callus and fibrous tissue, replacement of the fragment and fixation by one or more wire nails.

In the older fractures, the carpometacarpal joint is unstable, allowing to-and-fro motion of the metacarpal bone on the greater multangular in these, disability may be rather pronounced, both from the instability and from the arthritic changes which follow

In the presence of advanced arthritic changes arthrodesis of the carpometacarpal joint is the procedure of choice Although this does not restore a normal thumb the symptoms are relieved and motion in the remaining joints is sufficient to provide a fairly functional member

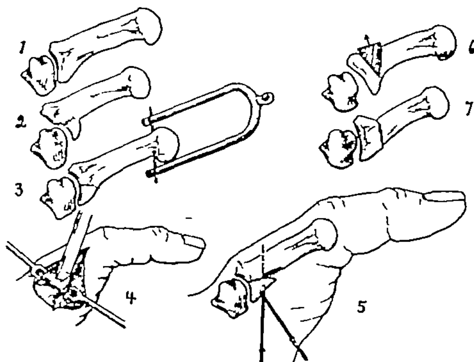


Fig. 431—Bunnell technic fo malunited Bennett's fracture (1 2 and 3 represent technic for fresh fractures not applicable to this section) 4 and 5 In relatively recent malunions, bone exposed through L-shaped incision, malunion broken up, and fragments replaced and fixed by stainless steel pins. 6 For malunion of long standing, cuneif rm wedge of bone removed as indicated by shaded area. 7 Restraining hook of metacarpal bone re-established by wedge osteotomy (Fro Bunnell, S. Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.)

Bunnell suggests another approach for cases wherein instability is pronounced and arthritic changes are of slight degree. To provide better stability a cuneiform wedge of bone is removed from the dorsal aspect of the base of the metacarpal bone the distal fragment is then tilted backward and allowed to unite in this position. By this procedure the projecting anterior edge of the base of the metacarpal bone is again in a position to hook over the front of the greater multangular bone, and thus prevent backward subluxation of the metacarpal bone on the greater multangular bone.

Malunion of the Phalanges of the Fingers

In the phalanges, following osteotomy and correction of the deformity a banjo splint or other form of apparatus, with rubber band, skeletal or pulp traction to the finger is required until union is solid.



Fig. 433.—*A* Malunited fracture of metacarpal bone with marked dorsal bowing can cause disability from interference with normal action of intrinsic muscles. *B* Restoration of length and alignment following insertion of intramedullary peg.



Fig. 486.—A Malunited fracture of phalanx. B Satisfactory result after intramedullary bone peg.

The results from operations for malunited fractures of the hand are likely to be disappointing, since there is usually some limitation of motion in adjacent joints from operative trauma and immobilization, and a consequent tenosynovitis.

In old fracture-dislocations of the proximal finger joints, function may occasionally be restored by arthroplasty For fracture-dislocations of the middle or distal finger joints of long standing restoration of motion by reconstruction procedures is unlikely, usually, arthrodesis with the finger in a functional position is preferable

The conscientious surgeon will often make every attempt to save a finger which is almost hopelessly mangled We agree with this policy In many cases despite malunion associated with extensive cicatrices and stiffness or rigidity of the joints, function is sufficient to warrant preservation of the member On the other hand, a finger which is beyond salvation by reconstructive measures and is an impediment to ordinary activities had best be amputated preferably through the middle finger joint. The thumb is an exception to this rule. Usually any thumb is preferable to none at all



Fig. 427.—Malunited *fracture* of middle phalanx with ankylosis of distal phalangeal joint from soft tissue injury and infection. Motion preserved in middle finger joint. Reduction and fixation with intramedullary metallic pin. This technic not *applicable* if distal finger joint is normal.

References

Barnard, L., and Stubbins, S. G Styloidectomy of the Radius in the Surgical Treatment of Non Union of the Carpal Navicular A Preliminary Report, J Bone & Joint Surg 30-A: 98, 1948.

Bennett, George E.: Discussion of Paper of Willis C. Campbell on Malunited Colles' Fractures, J A. M. A. 109 1107, 1937

Blount, W P Blade-Plate Internal Fixation for High Femoral Osteotomies, J Bone & Joint Surg 25 319, 1943.

Bognar: Quoted from Eliason: Ann. Surg. 96 28, 1932

Boyd, Harold B.: The Treatment of Malunited Fractures of the Ankle, Am. Acad. Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Mich. 1944, J W Edwards.

Boyd, H. B., and Knight, R. A. Fractures of the Astragalus; South. M. J 35 160 1942.

Boyd, Harold B., and Stone, Mario M.: Resection of the Distal End of the Ulna J Bone & Joint Surg. 26 313 1944.

Brett A. L. Operative Correction of Genu Recurvatum, J Bone & Joint Surg 17 984, 193..
Bunnell, Sterling: Surgery of the Hand, Philadelphia, 1944 J B. Lippincott Co.
Campbell Willis C. A Textbook of Orthopedic Surgery Philadelphia, 1930, W B. Saunders Co.
— Malunited Colles' Fractures, J A. M. A. 109 110., 1937
— Malunited Fractures, Surg Gynec. Obst. 66 460, 1938
— Malunited Fractures and Unreduced Dislocations About the Elbow J A. M. A. 92 122, 1929
Carmack, J C. and Hallock Halford Tibiotarsal Arthrodesis After Astragalectomy A Report of Eight Cases, J Bone & Joint Surg 29 476, 1947
Conn, Harold R. The Treatment of Fractures of the Os Calcis, J Bone & Joint Surg 17 392, 193.
Darrach, W *Anterior Dislocation of the Head of the Ulna, Ann. Surg. 56: 802, 1912.*
—: Habitual Forward Dislocation of the Head of the Ulna, Ann. Surg 57 928, 1913.
Darrach W Colles' Fracture, New England J Med. 226 594, 1942.
Darrach, W Forward Dislocation at the Inferior Radio-Ulnar Joint, with Fracture of the Lower Third of the Shaft of the Radius, Ann. Surg. 56 801 1912
Darrach, W., and Dwight, K.: Derangements of the Inferior Radioulnar Articulation, Med. Rec. 87: 708 1915
Durman Donald C. Discussion of Paper of Willis C. Campbell on Malunited Colles Fractures, J A. M. A. 109 1108 1937
Eliason E. L. An Operation for Recurrent Inferior Radioulnar Dislocation Ann. Surg 96 27 1932
Gallie, W E.: Subastragalar Arthrodesis in Fractures of the Os Calcis, J Bone & Joint Surg 25 731, 1943.
Ghormley R. K., and Mroz, R. J Fractures of the Wrist. A Review of 176 Cases, Surg Gynec. Obst 55 377 1932.
Hallock Halford Arthrodesis of the Ankle Joint for Old Painful Fractures, J Bone & Joint Surg 27 49 1945
Hart, V L. Arthrodesis of the Foot and Ankle in Military Surgery, Am. Acad Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities Ann Arbor Michigan, 1944, J W Edwards.
Henderson M. S. and Stuck, W G Fractures of the Ankle Recent and Old, J Bone & Joint Surg 15 882, 1933.
Inclan A B. A Clinical Case of Bad Union of Colles Fracture and the Significance of Its Orthopedic Repair Cir ortop. y traumatol. 4 63, 1936.
Key J Albert and Conwell, H. Earle: The Management of Fractures, Dislocations and Sprains, ed. 4 St. Louis, 1946 The C. V Mosby Co.
Knight, Robert A. Treatment of Fractures of the Tibial Condyles, South. M. J 38 46 1945
Lexer Erich Die gesamte Wiederherstellungschirurgie zugleich 2 Aufl., Leipzig, 1931 Johann Ambrosius Barth.
Lippmann R K: Laxity of the Radio-Ulnar Joint Following Colles Fracture Arch Surg. 35 .7* 1937
Little, Norman Sudeck's Atrophy M. J Australia 1 263, 1939 Abst., Year Book of Industrial and Orthopedic Surgery 1940
Mercer, Walter: Orthopedic Surgery Baltimore, 1936, Wm. Wood & Co., p 79
Meyerding Henry W Malunion of the Radius and Ulna Preventing Closing of the Hand and Flexion of the Wrist, S. Clin. North America 12 874, 1932.
Milch, Henry Cuff Resection of the Ulna for Malunited Colles Fracture, J Bone & Joint Surg 23: 311, 1941.
Milch, H.: So-Called Dislocation of the Lower End of the Ulna, Ann. Surg 116 282, 1942.
Milch, Henry *Dislocation of the Inferior End of the Ulna, Am. J Surg 1: 141 1926.*
Miller, O L., and Baker L. D: Fractures and Fracture Dislocations of the Astragalus, South. M J 32 125 1939
Mumford, E. B. Roentgenotherapy in Acute Osteoporosis J Bone & Joint Surg 20 949 1938.
Schumm, Herman C. Malunited Fractures About the Hip, Am. Acad. Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944, J W Edwards.
Scudder Chas. L *The Treatment of Fractures, Philadelphia, 1926, W B. Saunders Co.*
Speed, J S., and Boyd, H. B.: Treatment of Fractures of the Ulna with Dislocation of the head of the Radius (Monteggia Fracture) J A. M. A. 115: 1699, 1940.
Speed J S., ando Knight, Robert A The Treatment of Malunited Colles Fractures, J Bone & Joint Surg. 27 361 1945
Speed, J S., and Boyd, H. B Operative Reconstruction of Malunited Fractures About the Ankle Joint, J Bone & Joint Surg 18 270, 1936.
— Fractures About the Elbow Am. J Surg 38 727 1937

Steindler Arthur, and Marxer John Louis: The Traumatic Deformities and Disabilities of the Upper Extremity, Springfield, Illinois, 1946 Charles C Thomas.
Sutherland, Ross, and Rowe, M J., Jr: Metal Block Replacement of Bone Deficiency A Preliminary Report on an Operative Correction for Genu Recurvatum, J Bone & Joint Surg 26 118, 1944.
Sutherland, Ross, and Rowe, M. J, Jr: Tibial Epiphysiotomy for Severe Genu Recurvatum, Surgery 10 927 1941.
Taylor G W., and Parsons, C L.: The Role of the Discus Articularis in Colles Fracture, J Bone & Joint Surg 20: 149, 1938.
Thornton, Lawson A Plastic Operation for Reduction of Old Transverse Fractures of the Distal End of the Radius, Healed With Displacement and Deformity, Surg Gynec. Obst. 42 844 1926.

CHAPTER X

DELAYED UNION AND NONUNION OF FRACTURES

Although the physiologic and pathologic differences between delayed union and nonunion are those of degree only, the indications for operation and the procedures followed are entirely different Since a number of factors are involved in the process of consolidation of a fracture, one cannot fix an arbitrary time when a given fracture should unite, nor any definite period at which a state of nonunion may be said to exist. Union is regarded as delayed when healing does not progress at the rate anticipated for the location and type of the fracture So long as there is evidence either clinically or roentgenographically, that the process of repair has not ceased, the solidification of the fracture should be regarded as delayed.

As a rule a fracture should not be considered ununited until the process which is responsible for the condition is complete and osseous union is obviously impossible or highly improbable. The ultimate status may be one of three types (1) a typical pseudarthrosis (2) fibrous union, with osteoporosis of the fragments, or with atrophy of disuse and (3) fibrous union with sclerosis of bone.

(1) A typical pseudarthrosis is characterized by the formation of a shallow cup usually on the proximal fragment, which apparently is the result of greater functional stimulation of this fragment. Comminuted fragments are frequently fused into the periphery of the cup Callus or new bone forms on each fragment, rather than across the line of fracture, obliterating the medullary canal this bone is sclerosed and of an inferior quality comparable to dense scar tissue. (2) Fibrous union with osteoporosis is characterized by rapid, irregular absorption of lime salts as evidenced by mottling of the fragments. The pathologic process extends a considerable distance from the site of fracture on each fragment, and is apparently produced by a vasomotor phenomenon of the sympathetic nervous system as a reflex instigated by acute trauma After every fracture there is more or less absorption of the ends of the fragments, with increased circulation, probably from the same cause. In other words, the extreme osteoporosis associated with nonunion may be regarded as a natural process of healing which becomes exaggerated to a pathologic degree Bone atrophy of disuse is manifested by the paleness of the osseous structure and a diminution of the transverse diameter The fragments also lose their natural contours, assuming a conical shape. The marrow is increased at the expense of the cortex, which becomes thinner than normal At operation, excessive fatty infiltration of the marrow is observed. Bone atrophy of disuse progresses with the passage of time, from loss of functional stimulation to cellular activity which maintains the normal size of the bone (3) Sclerosis of the ends of the fragments for varying distances adjacent to the fracture constitutes a most serious obstacle to the induction of union by means of bone grafts. Excessive callus of poor quality is frequently associated with increased density of the fragments. Both the bone and the adjacent excessive scar tissue are relatively avascular

In fractures of the shafts of the long bones usually six months elapse from the time of the fresh fracture until nonunion is established. The interval varies,

Fig. 438.—*A* Typical pseudarthrosis of lower third of humerus, with shallow cup on proximal fragment. *B* Solid union after onlay bone graft dimension of bone increased.

Fig 439.—*A* Nonunion of fracture of humerus with marked osteoporosis of fragments. *B* Solid union six months after operation.

however union has been secured after a much longer period, especially following some local complication, as infection. In contrast, a definite status of nonunion can exist after two months in central fractures of the neck of the femur

Certain salient facts regarding delayed union or nonunion are worthy of consideration

Rarely is there definite clinical evidence of a constitutional factor in nonunion or delayed union In 1923, Campbell called attention to the influence of multiple fractures on these conditions Just how the number of fractures affects union is speculative, although the explanation may be that nature is unable to meet the excessive demand for bone production.

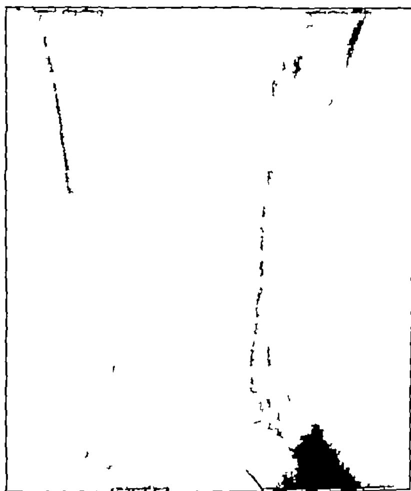


Fig 440.—Ununited fracture of humerus in patient aged fifty two years, with atrophy of disuse, as evidenced by cone-shaped fragments and thinning of cortex. Solid union after onlay bone graft.

As a rule sclerosis of bone results from a local pyogenic lesion, or other local causes, or it may be only a local manifestation of a constitutional disease, as syphilis. Again, the lesion may be of undetermined origin, resembling Albers-Schonberg s disease, or marble bones. In any event the bone is hard, dense, and deficient in circulation and osteogenetic powers.

In children differences in the structure of bones may be caused by constitutional or local disturbances. The constitutional factor cannot be explained, but the local disturbance may be due to an embryologic deficiency as found in congenital bowlegs or in so-called congenital fractures.

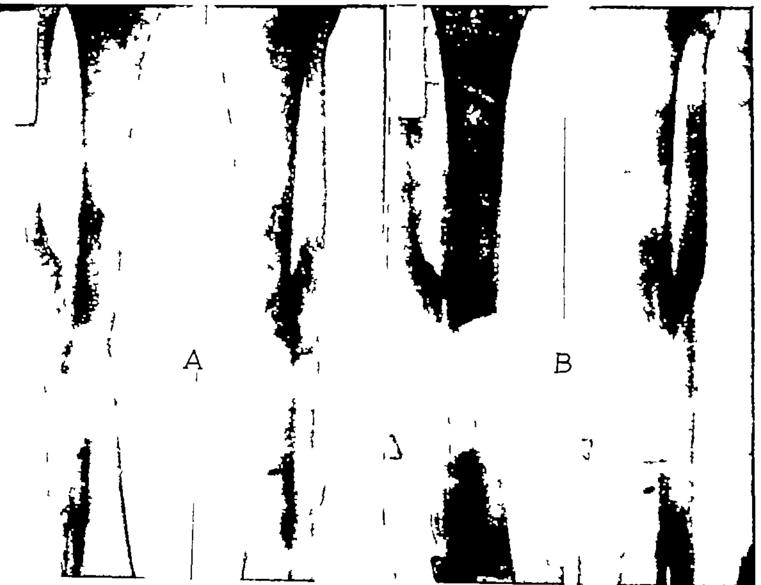


Fig 441 —A Nonunion with sclerosis of fragments from infection of compound fracture. B After first stage, reaction of sclerotic bone preliminary to massive sliding graft. (Case of Dr Dana Street, Kennedy General Hospital, Memphis, Tenn.)

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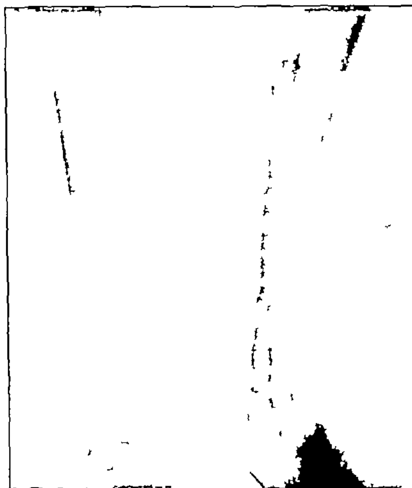


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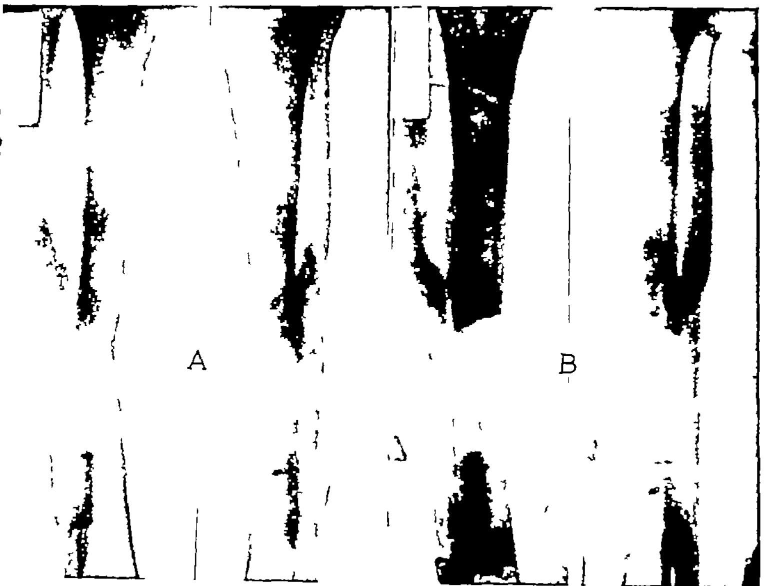


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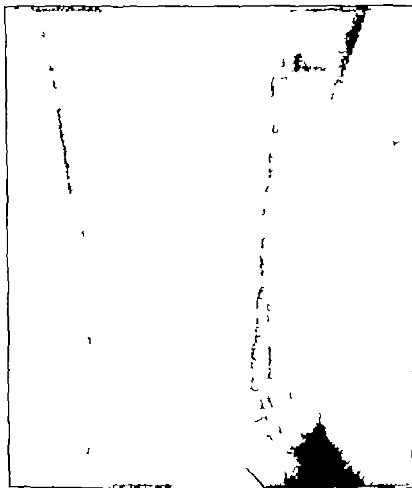


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In children, differences in the structure of bones may be caused by constitutional or local disturbances. The constitutional factor cannot be explained, but the local disturbance may be due to an embryologic deficiency as found in congenital bowlegs or in so-called congenital fractures.

to fractures with delayed union wherein the position and alignment are comparatively normal The prime advantages of the Phemister procedure are obvious i e., minimal surgery, minimal vascular disturbance, the simplicity of the operation, and the normal collapsing action of the muscle tone at the fracture site. If because of malposition, dissection must be rather extensive, the routine onlay bone-graft procedure is probably more suitable In lieu of the use of a cortical graft from the opposite tibia bone from the bone bank may be used for the cortical portion, supplemented by fresh cancellous bone or, all the grafts may be removed from the ilium. By these technics, the jeopardy to the opposite leg is obviated and early ambulation with crutches is permissible.

Technic (Phemister).—In exposure of the bone, dissection of the periosteum and soft tissue structures from the fracture site should be restricted to a minimum If the host bone is uneven, the protruding portions are chiseled away to create a level surface for contact with the cortical graft The fibrous intermediary callus is undisturbed. (Bony union takes place between the fragments and graft The intermediary callus, under protection from trauma, is replaced by bone or if a pseudarthrosis is present the cavity between the fragments eventually fills in with callus.) The fracture site is bridged by an ordinary whole-thickness onlay graft or by two smaller grafts. Cancellous bone is applied to the exposed fracture line on both sides of the graft. The onlay bone graft is maintained in relation with the host bone by suture of the periosteum and soft tissue structures tightly over the transplanted bone.

After Treatment.—External fixation is enforced by means of a plaster cast for two to three months, depending upon the location of the fracture, the size of the bone and the progress of the union.

Drilling of Fragments for Delayed Union

This method of inducing union is not new Andrews, in 1919, noted that multiple drilling for nonunion or delayed union was even then an old fashioned operation Brenard, a pioneer surgeon employed a procedure wherein six to twenty small holes were drilled obliquely through the fragments or through the fracture site By this measure osteogenesis may be stimulated through the increased circulation to the fractured surfaces from the periphery of the bone.

The technic of drilling will be given as applied to the lower third of the leg since the operation is more often employed in this location The same principles are appropriate however to fractures in other regions. This procedure is indicated if at eight weeks, the fracture shows little evidence of union.

Technic.—An incision three inches in length is made at the lateral border of the tibia over the fracture site. The skin is retracted medially and the subcutaneous structures are incised in a straight line down to the bone. The periosteum is stripped from the bone for a distance of one or two inches on the anterior and lateral aspects of both fragments With a No 30 drill, five holes are made into each fragment and across the line of fracture Some surgeons advise dissection of the scar tissue from between the fragments this is probably neither necessary nor advisable The lateral surface of the tibia should be freshened and a few sliver grafts of iliac bone placed across the fracture site.

In the vast majority of cases delayed union or nonunion is entirely a local problem, dependent upon the anatomy and physiology of the fractured bone, the type and degree of injury to the bone or adjacent soft tissues, and the efficiency of the treatment. Any factor, therefore, which interferes with the blood supply or the delicate process of repair contributes to delayed union or nonunion.

The treatment, also, is local. Of course, the patient should be placed in the very best physical condition, but, other than this, no constitutional treatment is of value. In a series of patients with ununited fractures Henderson, Kellogg Speed and Campbell have estimated the calcium phosphorus index and have found no abnormalities which have a bearing on nonunion. Calcium therapy is ineffectual in the treatment of either fresh fractures, or those in which a status of delayed or nonunion exists.

There is no place in surgery of the bones wherein physiologic principles are more applicable than in the management of delayed union and nonunion of fractures.

DELAYED UNION OF FRACTURES

The treatment of delayed union is largely conservative, consisting principally of efficient fixation. Function, however should be permitted to the maximum degree commensurate with fixation. In the upper extremity exercise of the fingers and of the shoulder is often the only function possible. In the lower extremity weight-bearing with the limb snugly encased in a walking cast is enforced, a definitely beneficial action on the consolidation of the fracture frequently being thus produced. This method of treatment may be continued from four to eight weeks. If the fracture is so located that motion in the knee is feasible hinges with a drop ring catch may be incorporated in the cast to allow passive motion of the knee joint.

In delayed union, open operations are of course necessary following a poor reduction to remove interposing tissue and approximate widely separated fragments. If the fracture is in an area wherein union is readily obtained, the technics described for fresh fractures may be employed.

If apposition and reduction are satisfactory and union is delayed after three months of efficient treatment, the question may arise as to the best method of procedure whether conservative measures or treatment as if nonunion were definitely established is advisable In fractures of the upper extremity particularly of the shaft of the humerus, the social and economic status of the patient must be considered. One is often justified in undertaking more extensive and reliable procedures, rather than risk an unduly prolonged convalescence. One must bear in mind however that until at least six or eight months have elapsed there is still a possibility of securing union by continued fixation.

Only the Phemister technic of onlay bone graft without internal fixation, and the operation of drilling of the fragments will be described for delayed union. Other methods, such as friction or trauma to the ends of the fragments, are not dependable

Onlay Bone Graft Without Internal Fixation

Phemister describes an onlay technic for the treatment of definitely established ununited fractures. His procedure we feel, is particularly applicable

to fractures with delayed union wherein the position and alignment are comparatively normal The prime advantages of the Phemister procedure are obvious i.e., minimal surgery minimal vascular disturbance, the simplicity of the operation, and the normal collapsing action of the muscle tone at the fracture site. If, because of malposition dissection must be rather extensive, the routine onlay bone-graft procedure is probably more suitable In lieu of the use of a cortical graft from the opposite tibia bone from the bone bank may be used for the cortical portion, supplemented by fresh cancellous bone or, all the grafts may be removed from the ilium By these technics, the jeopardy to the opposite leg is obviated and early ambulation with crutches is permissible

Technic (Phemister)—In exposure of the bone, dissection of the periosteum and soft tissue structures from the fracture site should be restricted to a minimum. If the host bone is uneven, the protruding portions are chiseled away to create a level surface for contact with the cortical graft The fibrous intermediary callus is undisturbed. (Bony union takes place between the fragments and graft The intermediary callus, under protection from trauma, is replaced by bone, or if a pseudarthrosis is present the cavity between the fragments eventually fills in with callus.) The fracture site is bridged by an ordinary whole-thickness onlay graft or by two smaller grafts. Cancellous bone is applied to the exposed fracture line on both sides of the graft The onlay bone graft is maintained in relation with the host bone by suture of the periosteum and soft tissue structures tightly over the transplanted bone

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Drilling of Fragments for Delayed Union

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The technic of drilling will be given as applied to the lower third of the leg since the operation is more often employed in this location The same principles are appropriate however to fractures in other regions. This procedure is indicated if, at eight weeks, the fracture shows little evidence of union.

Technic.—An incision three inches in length is made at the lateral border of the tibia over the fracture site. The skin is retracted medially and the subcutaneous structures are incised in a straight line down to the bone The periosteum is stripped from the bone for a distance of one or two inches on the anterior and lateral aspects of both fragments With a No 30 drill, five holes are made into each fragment and across the line of fracture. Some surgeons advise dissection of the scar tissue from between the fragments, this is probably neither necessary nor advisable. The lateral surface of the tibia should be freshened and a few sliver grafts of iliac bone placed across the fracture site

In the vast majority of cases, delayed union or nonunion is entirely a local problem dependent upon the anatomy and physiology of the fractured bone, the type and degree of injury to the bone or adjacent soft tissues, and the efficiency of the treatment. Any factor therefore which interferes with the blood supply or the delicate process of repair contributes to delayed union or nonunion.

The treatment, also is local. Of course, the patient should be placed in the very best physical condition, but, other than this, no constitutional treatment is of value. In a series of patients with ununited fractures Henderson, Kellogg Speed, and Campbell have estimated the calcium phosphorus index and have found no abnormalities which have a bearing on nonunion. Calcium therapy is ineffectual in the treatment of either fresh fractures, or those in which a status of delayed or nonunion exists.

There is no place in surgery of the bones wherein physiologic principles are more applicable than in the management of delayed union and nonunion of fractures.

DELAYED UNION OF FRACTURES

The treatment of delayed union is largely conservative, consisting principally of efficient fixation Function however should be permitted to the maximum degree commensurate with fixation. In the upper extremity exercise of the fingers and of the shoulder is often the only function possible. In the lower extremity weight bearing with the limb snugly encased in a walking cast is enforced, a definitely beneficial action on the consolidation of the fracture frequently being thus produced. This method of treatment may be continued from four to eight weeks. If the fracture is so located that motion in the knee is feasible, hinges with a drop ring catch may be incorporated in the cast to allow passive motion of the knee joint

In delayed union, open operations are, of course necessary following a poor reduction, to remove interposing tissue and approximate widely separated fragments. If the fracture is in an area wherein union is readily obtained, the technics described for fresh fractures may be employed.

If apposition and reduction are satisfactory and union is delayed after three months of efficient treatment, the question may arise as to the best method of procedure whether conservative measures or treatment as if nonunion were definitely established, is advisable In fractures of the upper extremity particularly of the shaft of the humerus, the social and economic status of the patient must be considered. One is often justified in undertaking more extensive and reliable procedures, rather than risk an unduly prolonged convalescence. One must bear in mind, however that until at least six or eight months have elapsed there is still a possibility of securing union by continued fixation.

Only the Phemister technic of onlay bone graft without internal fixation, and the operation of drilling of the fragments will be described for delayed union. Other methods, such as friction or trauma to the ends of the fragments, are not dependable

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If there is an associated fracture of the fibula in which the fragments are *overlapped and union is delayed* an additional small incision is made over the fibula at the fracture site and the fragments are freshened and engaged. If interlocking cannot be accomplished, *as in an oblique fracture* a rustless steel wire suture or a Vitallium plate is inserted to maintain apposition of the fibular fragments. This permits a firmer fixation of the tibial fragments, which is an important factor in promoting union



Fig. 442.—*A* Subcutaneous method of drilling for delayed union of tibia. Roentgenogram mad in operating room, with drill in situ to ascertain relation to fracture site. *B* Solid union two months postoperatively

After Treatment.—With the knee in 160 degrees flexion the extremity is placed in a walking cast from the groin to the toes. A window need not be cut over the wounds. The acute symptoms usually subside entirely within ten days. Thereafter walking with the aid of crutches is gradually resumed. The crutches are discarded at the *end of four weeks*. *Six weeks postoperatively* if the degree of union permits a new cast is applied, to which a drop ring joint is attached at the knee the joint may be locked, to hold the knee rigid for walking or released, to allow passive exercises of the knee. After four weeks. the second cast is removed and, if union is definitely solid, a leather lacer brace

with a drop ring joint at the knee is applied This apparatus is removed four to five months postoperatively depending upon the indications of the individual case.

In the event union does not progress the status is that of nonunion and a more radical and dependable treatment must be instituted If motion of 45 degrees or more is present in the knee, a bone-graft operation may be performed at once if there is only a slight range of motion and fibrous ankylosis is apparently impending a brace should be applied and exercises carried out at the knee for several months. Much depends upon the age of the patient. In young adults, the prospect of restoring function even with marked limitation of motion is always better than in older persons

The same principles of mobilization are applied in the treatment of joints adjacent to fractures of other long bones. The joints which should receive most attention are the elbow and knee. In the majority of cases other joints unless definitely injured or involved in a pathologic process, will become movable and recover good function merely by active use

NONUNION OF FRACTURES

In any case the treatment of an ununited fracture is a relatively extensive procedure and should not be recommended until a status of nonunion is definitely demonstrated, both clinically and by roentgenogram and union is obviously impossible or highly improbable without surgical intervention As compared with the number of fractures, the incidence of nonunion varies in each bone being from the highest to the lowest as follows tibia both bones of the fore arm humerus, and the femur

PREOPERATIVE CONSIDERATIONS

Since bone grafts are utilized for procedures other than nonunion or the bridging of defects, the general principles of bone grafting are described in the chapter on Surgical Technic Special considerations, however enter into bone grafting for nonunion or the bridging of defects. No fixed rules of treatment can be formulated for all cases. Each must be carefully surveyed and all of the various factors related to the nonunion evaluated Many of these are indefinite and are attended with such uncertainty that frequently the final decision as to treatment must be determined by that somewhat undependable quality known as surgical judgment. Paraphrasing an old quotation we may say that good surgical judgment is based upon experience experience entails a certain amount of poor judgment

Preoperative Reconditioning of the Extremity

In all ununited fractures, a more or less prolonged period of previous treatment entailing skeletal traction or cast immobilization has been carried out In addition the soft tissues have been damaged to a varying degree, from the original injury from surgery or from antecedent infection secondary to operations or to an original compound fracture These factors impair the normal physiologic activities of the extremity reduce its ability to combat infection and interfere with the restorative and regenerative powers

Reconditioning is especially important in infected compound fractures, wherein the presence of latent or dormant bacteria is always a possibility Venous and lymphatic stasis and poor blood supply are the common physiologic disturbances.

Restoration of active function combined with proper physical therapy for several months prior to reconstructive surgery has proved a practical method of reducing the possibility of postoperative infection and enhances the prospects of successful rehabilitation of the extremity following reconstruction

For a nonunion in good position, reconditioning may as a rule, be accomplished by supplying the patient with a brace which adequately supports the extremity and permits active use, mobilization of joints and weight bearing This not only improves the tone of the extremity as a whole, but is also of immeasurable benefit in improving the patient s general debility incident to prolonged recumbency Intensive physical therapy should supplement these measures. Since the bone ends are usually well embedded in dense fibrous tissue, weight bearing or mobilization of adjacent joints ordinarily is not painful and does not produce any harmful effects.

Nerve injuries, when present, should be carefully evaluated. If the nerve injury appears reparable, the nerve should be explored and repaired before bone grafting is undertaken. Occasionally it may be necessary to shorten the extremity to compensate for nerve defects Obviously the desirable time for such shortening is before treatment of the nonunion is instituted

If the nerves are damaged to such an extent that permanent loss of motor and sensory supply to the extremity is inevitable, amputation is usually the practical course

The Relation of Active Infection and Skin Defects to Bone Grafting

A preliminary or preoperative consideration of the status of the soft parts over the defect in the bone is usually as important as that of the status of the bones themselves. Extensive cicatrices of the skin and deep tissues are usually the result of compound fracture associated with infection Nonunion associated with draining sinuses, cavities, sequestra, foreign bodies or extensive scarring may necessitate two- or more stage procedures before rehabilitation of the extremity is complete In the presence of an active infection or draining sinus, even though of the lowest grade any bone-grafting operation for nonunion is contraindicated.

Eradication of Cavities, Sequestra, Draining Sinuses, and Skin Defects.—During World War II, many surgeons reported on the early eradication of draining wounds and chronically infected bone cavities following traumatic osteomyelitis. Treatment was carried out in one two three, or even four stages. Coleman and associates operated on 52 infected bone defects or cavities, filled them with cancellous grafts after sequestrectomy and closed the wounds with a full thickness skin covering The results were successful in 92 per cent. Knight and Wood were successful in 21 of 23 cases with a three-stage procedure sequestrectomy split thickness graft, and at a last stage, simultaneous filling of the cavity with bone chips, covering the chip-filled cavity with a full thickness skin graft. Kelly and associates preferred a more conservative course they noted that the use of bone chips as fillage, concurrent with a full thickness skin

covering, was frequently followed by prolonged postoperative drainage, that the interstices between the chips were filled with infected granulation tissue. When and if these wounds healed, they presented at least as great a potential for recurrence of infection as the original lesion prior to treatment Consequently, they preferred fat, muscle flaps, or inert acrylic molds as fillage, bone grafting being carried out only after a healed full thickness covering was provided.

For eradication of cavities alone, the shorter courses may be justified. There is no justification, however, for any short-cuts in the treatment of nonunion or for bridging defects. It is absolutely essential as a prerequisite that skin over the operative field be full thickness, stable, and of good turgor To provide this, three preliminary stages may be necessary The first stage consists of thorough saucerization of the soft tissue wound and bone, removing all foreign and infected material sequestra, and devitalized soft tissue, thereby eliminating all "dead space" and providing a vascular bed. The parenteral administration of penicillin is accompanied by a local pressure penicillin dressing Four to seven days later a thin layer of granulation tissue covers the saucerized wound. At the second stage, split thickness grafts are applied to the granulating surface. Four to six weeks after healing of the free grafts, full thickness coverings replace the dermatone grafts, subcutaneous fat or muscle flaps being used for fillage At the final stage of reconstruction bone grafting for nonunion or defects is not carried out until the skin graft is well stabilized, eight to twelve weeks postoperatively

Prevention of Excessive Shortening and Malalignment in Infected Fractures—Many compound fractures present an open draining wound at the site of fracture with marked displacement and shortening of the bone fragments. In certain of these, it is advisable to realign the fragments through the infected wound, rather than to wait until the wound has healed and the infection has subsided before beginning the reconstruction program Although there is some risk to such an operation, there are also definite advantages

Metallic internal fixation may be employed without fear of serious complications, even in the presence of a low-grade infection. Usually however removal of the foreign material will be necessary before the wound will heal. This can be done after the fracture has become stabilized by fibrous tissue in a desirable alignment and position. The advantages gained are obvious. Unless bone has been previously lost excessive shortening of the extremity is prevented surgical trauma at the time of the bone-grafting procedure is reduced to a minimum as resection and wide mobilization of the fragment ends to obtain reduction is unnecessary The less the soft tissues and bones are traumatized at the time of the bone graft the less the danger of a postoperative exacerbation of the infection. In four of our cases, fracture united during the observation period obviating the necessity for a subsequent bone-grafting procedure Such an occurrence is, of course the exception rather than the rule.

Status of the Bones Prior to Bone Grafting

Osteoporosis—In general it may be stated that osteoporosis in the shaft of a long bone enhances the prospect of restoration of union Although the medullary structure may be partly replaced by fat, the cortical portion is soft

viable, and has an abundant blood supply If local inhibiting factors, such as separation of the fragments interposition of scar tissue and sealing off the medullary canals at the ends of the fragments are corrected, the reparative process of callus production may usually be reactivated by the mechanical fixation and stimulus to osteogenesis afforded by a bone graft.

Ununited fractures of the shaft of the long bones in the aged unite equally as well as in young adults, and, in some cases, even more rapidly

Sclerosis.—Frequently the ends of the fragments are sclerosed for varying distances adjacent to the fracture even without a previous infection. The sclerosis definitely contributes to the nonunion and constitutes the most serious obstacle to the induction of a union by means of bone grafts. An excessive amount of callus of poor vitality is often associated with the sclerosis.

In many cases, union has been obtained in the presence of sclerosis of the fragments for one to two inches adjacent to the fracture site though the process of union is extremely slow months frequently elapsing before the fracture line is obliterated Union takes place first between the graft and the more vascular portions of the shaft Callus gradually wipes over the fractured area similar to the way a lead pipe is wiped and joined together

Although the grafts aid materially in reactivating the process of bone repair they will not maintain the stability of the fractures indefinitely and will eventually fracture unless the fragment ends unite by end to-end endosteal and periosteal callus. Any tension or motion at the fracture site tends to weaken the grafts and to delay union across the fracture line After removal of the casts, the extremity should be protected by means of a brace until roentgenologic evidence of union is conclusive

The number of bony unions obtained by a single or dual massive onlay graft in the presence of varying degrees of sclerosis, is sufficiently high to warrant their use in most cases as the primary procedure

Nonunion With Healed Infection

Subsequent discussion will be limited to that group of infected compound fractures which manifest no outward or clinical signs of active infection, and in which the soft tissue defects have been eliminated or repaired.

In considering a reconstruction program for previously infected compound fractures with nonunion, the question of major importance is as follows When is it advisable to perform a bone graft? The term advisable, rather than safe is used intentionally since, in many cases, there is never a safe time. It may often be advisable to proceed with the bone-grafting procedure, accepting a certain amount of known risk, rather than to wait indefinitely or to abandon the operation entirely On the contrary as Dickson mentions, the materials at our disposal for bone grafting are not unlimited, and must be carefully husbanded it is embarrassing to lose a graft from infection No certain means of determining whether an infection has been completely eradicated, or is merely quiescent and dormant, is available Considering this problem the following factors must be taken into consideration the time elapsed the character and duration of the previous infection and finally the general condition of the extremity

The sulfa drugs and penicillin have made possible a much more aggressive program in the treatment of nonunion resulting from previously infected compound fractures. Massive preoperative and postoperative coverage with penicillin has materially reduced the danger of operative reactivation of old infections. Penicillin may be expected to wall off an active or inactive area of infection within the limits of the peripheral vascular zone, though it cannot be expected to sterilize an avascular field which it cannot penetrate. It is now the consensus that, in the majority of cases, reconstructive operations may be performed as early as four to six months after all signs of active infection have disappeared.

If the infection has been confined largely to the soft tissues or about sequestrated fragments, the probability of a postoperative reactivation is much less than if the infection has involved the cortex and medullary canal of the major fragments. If the infection has been a prolonged destructive process one may assume that all the surrounding structures have been deeply penetrated by the bacteria and therefore a dormant infection is more likely. Bacteria walled off in a cortical pocket may lie dormant for years and again become active following surgery or other trauma. Such surgical risks are inherent in the treatment of compound fractures and must be accepted.

Good turgor of the skin, pliable cicatrices, good circulation, the absence of edema and of exacerbation of infection from reconditioning activities or provocative attempts to produce a flare-up by preliminary surgery, massage or manipulation are favorable factors. The period of time which has elapsed is not alone a reliable index, however, with the elapse of time, the regenerative, reparative and protective mechanisms are given an opportunity to produce the favorable situations requisite to grafting.

Technics of Bone Grafting

Various measures have been described for the treatment of ununited fractures, which may be applied successfully to delayed union but are conspicuously unsuccessful in true nonunion. These may be enumerated: (1) denudation of fractured surfaces, reduction and fixation with absorbable or nonabsorbable sutures, or a steel plate; (2) plastic step up or dovetailed wedging of the bone with or without internal fixation; (3) drilling of the fragments; and (4) the use of various types of inadequate bone grafts, as chip grafts, Delagenière grafts, pegs, and intramedullary grafts. These procedures had been carried out in approximately 25 per cent of ununited fractures observed and, without doubt, have frequently been the actual causative agents of continued nonunion. In true nonunion, such methods should be abandoned, as the number of failures is entirely too large. Union is induced in some cases despite such measures, we cannot, however, be content with an occasional successful result through the processes of nature alone, but must utilize some means whereby osseous fusion may be obtained in the largest number of cases.

Three bones provide essentially all of the necessary sources for bone grafting: the ilium, the fibula and the tibia. The types of grafts, the technic of removal, and the particular advantages of each are described in the chapter on Surgical Technic.

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Various measures have been described for the treatment of ununited fractures, which may be applied successfully to delayed union but are conspicuously unsuccessful in true nonunion. These may be enumerated: (1) denudation of fractured surfaces, reduction and fixation with absorbable or nonabsorbable sutures, or a steel plate; (2) plastic step-up or dovetailed wedging of the bone, with or without internal fixation; (3) drilling of the fragments; and (4) the use of various types of inadequate bone grafts, as chip grafts, Delageniere grafts, pegs and intramedullary grafts. These procedures had been carried out in approximately 25 per cent of ununited fractures observed, and, without doubt, have frequently been the actual causative agents of continued nonunion. In true nonunion such methods should be abandoned, as the number of failures is entirely too large. Union is induced in some cases despite such measures; we cannot, however, be content with an occasional successful result through the processes of nature alone, but must utilize some means whereby osseous fusion may be obtained in the largest number of cases.

Three bones provide essentially all of the necessary sources for bone grafting: the ilium, the fibula, and the tibia. The types of grafts, the technic of removal, and the particular advantages of each are described in the chapter on Surgical Technic.

If refrigerated homogenous grafts prove satisfactory a modification of some of the more major bone-grafting procedures will eliminate some real dangers. Perhaps because of long usage it is the consensus that fresh autogenous bone is better tolerated and more rapidly revascularized than any other type of graft, we agree that this conclusion is biologically correct. It is however, frequently impossible or inadvisable to obtain adequate graft material from the patient for massive bone transplants Fresh homogenous bone is ideal so far as the recipient is concerned but is not ideal from the donor s viewpoint. The removal of a massive homogenous graft is a major surgical procedure and the period of disability for the normal donor is frequently prolonged and sometimes permanent hence, the supply of homogenous bone is justifiably limited. The bone bank appears to provide a satisfactory source for graft material. Although the use of refrigerated homogenous bone is still in a stage of clinical experimentation, sufficient data has been accumulated to indicate that it is a safe and effective source of graft material, and that a broad expansion of its use is justified in reconstruction surgery The supply is inexhaustible and apparently the bone may be kept indefinitely under proper refrigeration. After the graft has thawed it differs very little in appearance and physical characteristics from a fresh graft Thus far clinical experience in the use of refrigerated bone indicates that it exhibits a physiologic similarity We have used refrigerated homogenous bone grafts in twelve cases of nonunion. It is too early to form definite conclusions, yet we have not observed any definite differences, either clinically or roentgenographically from fresh homogenous bone. Perhaps, the modern hospital of the future will have to establish a 'parts department.

Massive cortical grafts, supplemented by cancellous bone offer the best prospect of fixation and osteogenesis for nonunion of long bones. The onlay massive sliding and inlay grafts are more commonly employed. Intramedullary grafts are used in only a few locations. At one time popular on account of the ease with which they were inserted intramedullary grafts have not been uniformly successful and as a consequence, have been practically discarded. The inlay graft was first used by Albee. The term onlay graft ' was originated by Campbell although his technic, described below is a modification of Henderson s procedure The massive sliding graft was described by Gill. From these basic procedures, many modifications and combinations have evolved.

In the treatment of ununited fractures, regardless of the type of graft utilized certain principles must be observed

1 The preliminary reconditioning (see above) is carried out thoroughly and efficiently to provide a receptive host.

2. Excessive scar tissue at the fracture site is excised to insure a vascular and relatively normal soft tissue investment for the graft.

3 In so far as possible, soft tissue attachments of the host bone are preserved

4 The ends of the fragments are resected to relatively normal bone, provided this does not entail too much shortening If the shortening is extensive, procedures for bridging defects are applicable (p 703)

5 If the fragments are in good position, removal of scar tissue from between the fractured surfaces may be inadvisable

6 The fragments of the host bone must be closely apposed.

7 Grafts should be placed as far from the skin surface as practicable

8 Cortical grafts must be supplemented generously by cancellous grafts.

9 The excessive use of foreign materials is to be avoided Although inert metals are well tolerated in nonunion we do not believe that metal plates can take the place of grafts. The use of metal plates, even as supplementary fixation, is seldom necessary or desirable

THE ONLAY BONE GRAFT

In 1921, after average success in the treatment of ununited fractures Campbell came to the conclusion that the end results might be improved by a method which would permit *absolute fixation* and at the same time *promote osteogenesis* He had previously employed massive intramedullary grafts inlay, and sliding grafts, motion at the fracture site could always be detected after these procedures. As a consequence, the onlay technic for ununited fractures of long bones was adopted. This method was derived from the Henderson operation and embodied the same principles, but differed in that the cortex was not removed from the fragments, autogenous bone nails were used, rather than beef bone screws, and the endosteal portion of the graft and cancellous bone from the upper extremity of the tibia were employed to promote osteogenesis

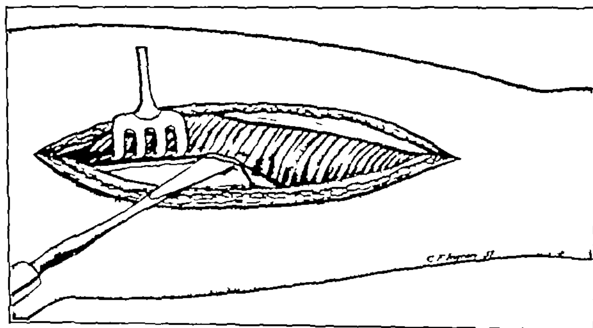


Fig. 442.—Exposure of nonunion of middle third of femur

The present Henderson and Campbell onlay technics differ only in minor details of preparation of the graft and of the host bone In the Henderson technic, considerably more bone is removed from the cortex of the host to create a flat surface down to vascular bony tissue a substantial portion of cancellous bone is left intact on the graft.

The onlay bone graft is applicable to nonunion of the shaft of any long bone The technic is similar for all only the size of the graft and the number of screws for fixation are modified to meet the requirements of the fractured bone.

To expedite this procedure, two teams work simultaneously The first team prepares the fracture site while the second removes and prepares the graft. The

second team aids the first as the graft and the fragments are being placed in proper position and fixed by screws. The wounds are closed more or less simultaneously By this coordination even the more difficult and lengthy bone-graft procedures, such as bone grafts to both bones of the forearm, may usually be consummated within the limits of tourniquet time.

Technic—An ample incision is made over the point of fracture, the fracture site is exposed, and all intervening scar tissue is removed. The periosteum of each fragment is incised for several inches, according to the length and size of the graft to be employed. The periosteum is stripped from the circumference from one-half to three-fourths inch, the soft parts, from which circulation is derived, being left attached so far as possible If apposition is perfect, the ends of the fragments need not be disturbed otherwise, the fragments are pared with a chisel or motor saw, and each medulla is reamed out to normal marrow tissue. With a chisel, "shavings" are removed from a portion of the circumference of the bone, forming a continuous flat surface the width of the graft and three or four inches in length on each fragment.

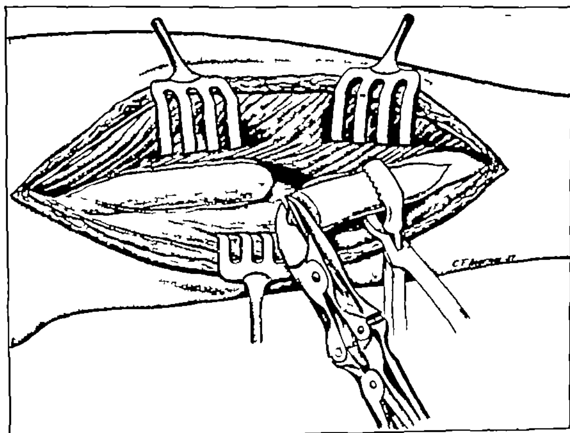


Fig. 444.—Excision of eburnated bone from ends of fragments. Soft tissue attachments to bone preserved as far as possible.

At the same time, a second surgical team removes from the tibia a full thickness massive cortical graft of sufficient length and width to permit fixation. With a motor saw the graft is split longitudinally through the edge into two parts, one consisting of a strong outer plate of dense bone or cortex, devoid of periosteum the other of the endosteum. For the larger bones, as the humerus, femur and tibia, the *cortical graft is left* as thick as possible. The other dimen

sions of the graft are proportionate to the size of the bone to be grafted. For the forearm, the cortical portion of the graft is purposely split to provide a bone plate only slightly thicker than the average metal plate

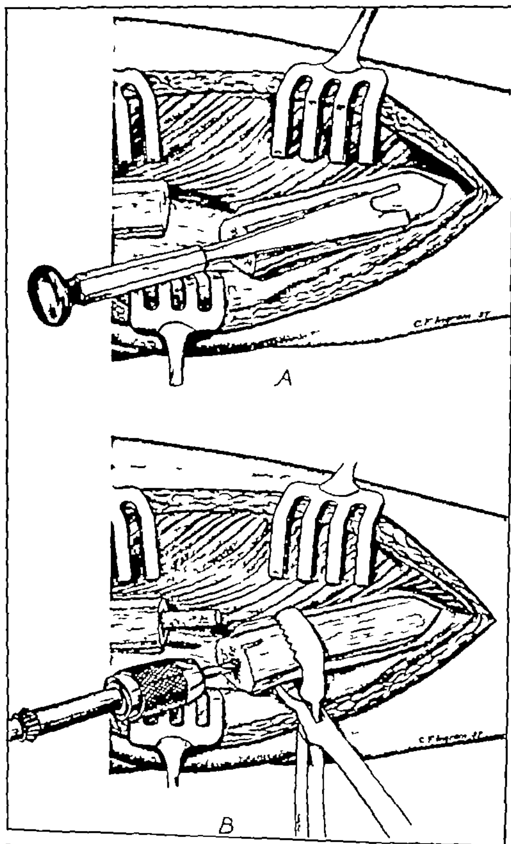


Fig. 445.—*A*, "Shavings" removed from small portion of circumference of shaft, forming flat surface three to four inches in length on each fragment. *B*, Each medulla is reamed out. Graft of endosteum placed in medullary canal as fracture is reduced.

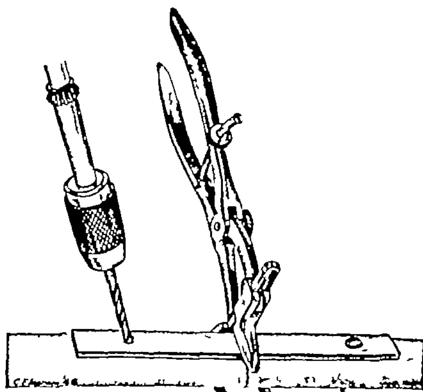


Fig. 446.—Fragments and cortical graft held in position by a bone clamp fixation secured by screws which traverse the graft and both cortices.

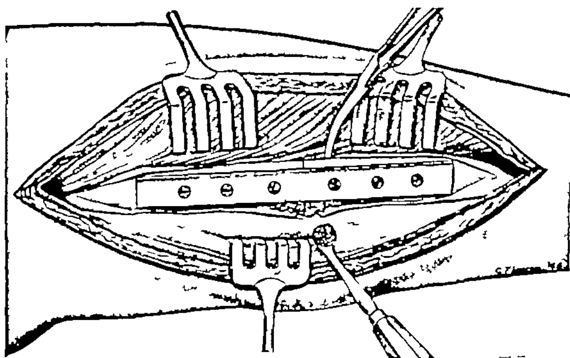


Fig. 447.—Onlay bone graft completed by insertion of cancellous bone about fracture site from medullary surface of graft and from tibial condyle.

As the fragments are reduced, a strip of endosteum *from the tibia* is inserted into the medullary cavity across the fracture site, the normal cancellous bone thus supplied *serves to promote osteogenesis* With the fragments apposed in normal alignment the strong outer plate of the bone graft is placed on the flat surface of the fragments, bridging the site of fracture and so held by a clamp The graft must not be applied under tension, otherwise, disintegration will follow, undoubtedly this is a factor in many fractures of the graft at the original site A ⅛ inch *hole is drilled through the graft* and through the cortices of the host, the hole being one inch distant from the end of the fragment. A screw of appropriate size and length is then inserted though not securely seated This allows a final impaction of the fragments and minor adjustments of the relation and alignment of the two fragments with the graft Fixation is completed by the insertion of three or more additional screws. *Ordinarily, a total* of four screws is adequate for all bones except the femur The screws in each case should be only sufficiently long to pass through the graft and the medial and lateral cortices of the bone they should not protrude excessively into the soft tissues on the opposite side. The two mesial screws should be *approximately* one inch from the fracture site Except in oblique fractures, a screw is not utilized to traverse the fracture site

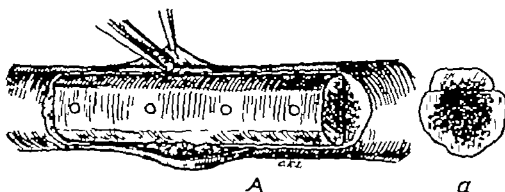


Fig. 448.—Henderson onlay bone graft. Cancellous bone is left intact on graft. A rather substantial segment of bone is removed from host fragments in preparation of bed

With a curette spongy or cancellous bone is removed from the condyles is still active, care must be exercised not to injure this structure with the curette, *of the tibia through the defect created by removal of the graft.* If the epiphysis as partial arrest of growth and deformity might be thus induced (p 542) The remainder of the endosteum and shavings, and the cancellous bone from the tibia are placed about the site of the fracture This last step in the procedure is an excellent adjunct to the massive graft, as spongy bone is more proliferative than any other

When the operation is complete, fixation should be sufficiently solid to prevent motion at the fracture site.

After Treatment.—Immobilization is insured by a plaster cast which is partially bivalved to allow *for postoperative* swelling or if preferred, the limb may be placed in an *appropriate* splint *After three weeks, the* postoperative reaction usually will have subsided. If *the arm* is the extremity affected a snugly fitting cast is then applied Eight to ten weeks postoperatively *the cast* is replaced by a reinforced leather corset, *in* which a hinge is incorporated at the adjacent joint or joints, that active *and* passive motion may be carried out as

soon as feasible. This brace is worn from two to four months, or until there is no doubt as to complete consolidation.

In the lower extremity, a walking cast is applied after two months and worn for a period of one month This is followed by a leather lacer brace the joint in the brace being, as a rule, held rigid for the first month. If repair follows an average course, free motion is allowed four months after operation.

In either the lower or upper extremity some form of support is usually maintained until the lapse of six months. One of the clinic patients, in whom the onlay graft was employed for nonunion of both bones of the forearm left the hospital without permission within twenty four hours after operation. He discarded all support within a few weeks, yet the final result was solid union and perfect function. The process of bone repair however is retarded in all ununited fractures and must be carefully guarded until consolidation is complete If the already deficient reparative process is further hampered by undue strain bone resorption may be stimulated, leading to complete dissolution and a return to the state of nonunion. Moreover a slight blow may fracture the graft and likewise destroy the efficiency of the fixation

By this procedure, union is accomplished within a shorter period of time. No motion can be detected following operation, thus movement may be permitted earlier in adjacent joints and function is conserved. The contour of the bone is not altered, and the graft actually increases the dimensions and strength of the bone In our experience the results have been uniformly successful in all long bones, regardless of the status or duration of the nonunion Despite a postoperative infection in thirty-one patients, in twenty nine of whom nonunion was associated with compound fractures, twenty four or 77 4 per cent, obtained solid union. Of a total of 251 ununited fractures, solid union was established following the use of the onlay graft in 235 or 93 6 per cent ' These are statistics from our cases prior to the use of sulfa drugs and penicillin fixation in this series was secured by square autogenous bone pegs. In 1941 Campbell and Boyd reviewed all the single onlay bone grafts used by the clinic staff in the treatment of 511 nonunions The end results were essentially the same as those quoted above Henderson, in 1944 reported the end results of onlay bone grafts at the Mayo Clinic from 1912 through 1942 inclusive. Of 657 onlay grafts to the long bones, 573 were successful (87 per cent)

Delayed Onlay Graft

If previous operations have been unsuccessful, a two-stage bone-grafting procedure may be advisable. In this event a large graft is removed from the tibia and replaced in its bed, and the periosteum is sutured above it Three to four weeks later if healing has taken place and the skin is in satisfactory condition, the graft is applied according to the method described above By the delay osteogenesis, as evidenced by new callus on the graft is already in progress before the transfer to the site of nonunion is made

The reported series of delayed bone grafts are not sufficiently large to permit an estimate of the value of this procedure. A small but brilliant series of delayed grafts for congenital pseudarthrosis was recently reported by Moore. This series and others suggest that, under unusual or difficult circumstances, the use of delayed grafts is worthy of consideration.

For osteosynthesis, Orell utilizes a viable immature, living bone, which he calls *os novum* This is prepared by implanting narrow strips of nonviable homogenous sterile bone (*os purum*) subperiosteally over the anteromedial surface of the tibia Two to three months after implantation, a profuse growth of new soft vascular bone is found in the clefts between the periosteum, the os purum, and the tibia This type of bone is appropriate when extraskeletal connective tissue separates two osseous surfaces which are to be joined through transplantation Orell states that, because of the proliferative power of os novum new bone forms rapidly after its use and more uniformly than after transplantation of normal autogenous bone Further, os novum is pliable and may be prepared without injury to fit practically any area This type of graft affords relatively little mechanical support and is therefore of no value for the purposes of fixation

Onlay Bone Graft Without Internal Fixation

Phemister feels that the trauma incident to an ordinary onlay bone graft is proportionately too great, and the amount of dissection is likely to lead to necrosis of the tissues, including the ends of the bone that the rigidly fixed graft may become fractured, and that infections are more common following this procedure than in operations of less magnitude which entail less trauma to the soft tissues and bone He feels that the ordinary onlay bone graft is based upon two erroneous teachings (1) that in all cases of nonunion, the fracture site must be broken up and scar tissue and medullary callus must be removed from the fragment ends (2) that the graft should be *firmly anchored* to the fragments for secure fixation It is his contention that, if the fragments of an established nonunion are in an acceptable position, these two steps are unnecessary and that a more simplified technic is adequate (p 610)

For delayed unions, and for a few established nonunions, we agree that such a procedure is relatively simple and satisfactory We feel, however that in most cases the routine onlay bone-graft procedure described above for established nonunions is necessary

Although in some respects advantageous, in other respects onlay bone grafts without fixation present certain disadvantages i e., the lack of internal fixation is likely to lead to malalignment This is particularly true of ununited fractures with overlapping of the *fragments* or marked angulation Some form of internal fixation (and the onlay bone graft is the most satisfactory) must be utilized if the alignment of the limb is to be *maintained*. External fixation, alone, is notoriously inadequate in most cases of this type.

DUAL ONLAY GRAFT

Because of the difficulty of securing bony union in congenital pseudarthrosis, Boyd, in 1941, developed a method of treating this condition with *dual bone grafts*. The usefulness of this procedure has been expanded to include other types of nonunion, particularly the bridging of defects (p 703) The single onlay bone graft is still employed in the majority of ununited fractures, for some of the more difficult and unusual nonunions, however the dual graft would seem to be preferable By this procedure, single onlay bone grafts are placed at opposite sides of the host bone, and are fixed by the same set of screws. The

grafts thus grip the two fragments in forceps fashion and provide firm fixation of the fracture The indications for the grafts are described below The technic of the procedure for bridging defects of bone and for congenital pseudarthrosis are described on p 707 and in Chapter XXV, respectively

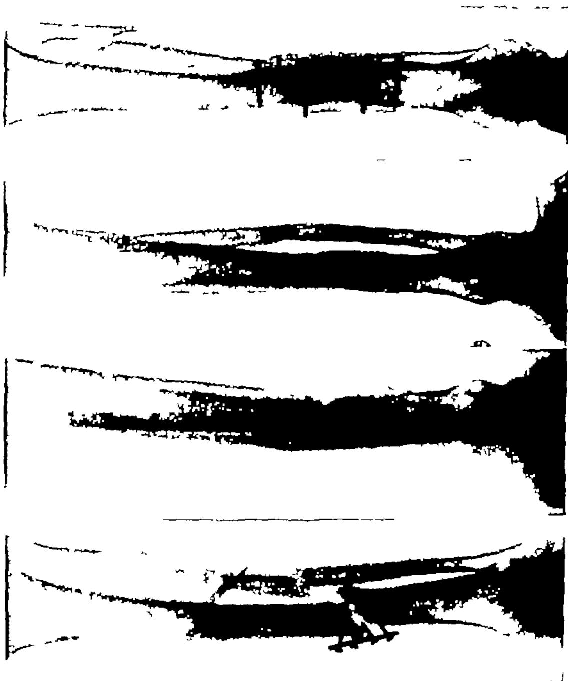


Fig. 449.—Nonunion of middle and lower third of tibia treated by dual onlay bone grafts.

Nonunion of Fractures Near Joints.—Adequate fixation of ununited fractures near the joints is a difficult surgical problem. Ordinarily the fragment nearest the joint is short thus, one cannot easily obtain secure mechanical fixation of the graft to the short fragment. This difficulty is usually increased by osteoporosis, and by the large amount of cancellous bone in the metaphyseal fragment. The thin cortex of the metaphysis does not lend itself well to ordinary

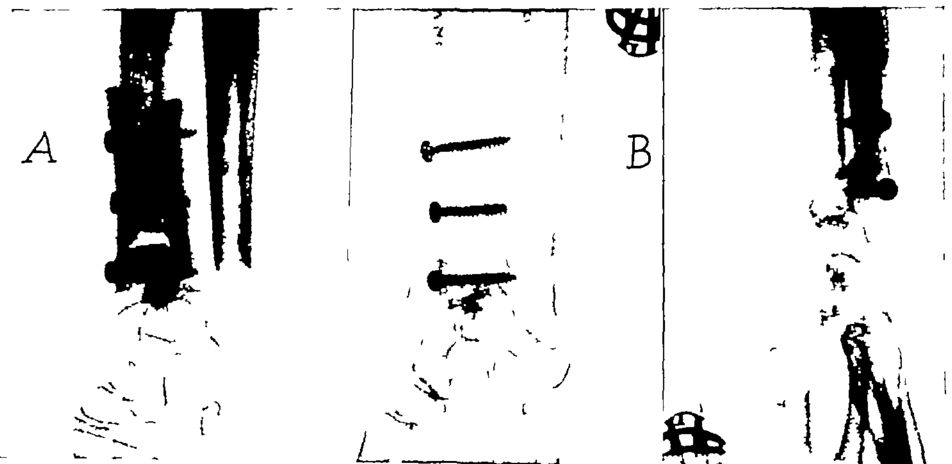


Fig. 450.—*A*, Dual bone graft for ununited Colles' fracture. Short osteoporotic distal fragment is difficult to hold in position by ordinary methods. *Dual onlay bone graft provides forcepslike action for fixation.* *B*, Eight months after operation, grafts and cancellous bone in trough are thoroughly fused with host fragments.

means by metallic fixation. These elements all jeopardize the fixation by a single graft. With the dual graft, the short metaphyseal fragment is adequately grasped between the ends of the two grafts, the hold of the threads being maintained in the cortical bone of the two grafts, rather than in the host bone The soft cancellous bone is thereby *compressed and held quite firmly by the* bone clamp"

Difficult Nonunions in the Shafts of the Long Bones.—In severe nonunions in the shaft of long bones, a single onlay bone graft may not provide sufficient fixation. As added insurance against failure of the operation, a dual graft may enhance the prospect of union This is particularly true of nonunion of the femur

If one fragment of a nonunion presents a conical-shaped or oblique end, rather than resect this portion and produce undue shortening or bridge an entire defect, one may approximate the conical end to the squared end of the opposite fragment, overcoming the deficiency in size and strength by two grafts.

A dual graft is a satisfactory means of re-establishing or increasing the size and circumference of a bone after previous failures of a sliding or inlay type of graft.

Osteoporotic Bone.—In elderly people with nonunion of the shaft of a long bone of long standing the host bone may present an extremely osteoporotic, eggshell cortex. The medullary portion of the bone is expanded proportionately, and is usually filled with a thin, yellow, fatty boggy material. Such a bone is not satisfactory for the insertion of screws, in fact the screws may be expected to pull out of the osteoporotic fragments with a probable loss of alignment and position The dual graft forms a bone clamp which compresses the osteoporotic fragments, so as to insure maintenance of alignment and position until the normal reparative processes have advanced sufficiently to stabilize the fracture.

Bishop and associates in addition to the above indications for the use of the dual graft employed it in cases wherein one or both ends of the fragments were sclerotic. If the sclerosis does not extend too far from the fracture after the ends have been squared, we would agree with this indication. If sclerosis is more extensive probably the massive sliding grafts are more suitable.

Of 358 cases wherein Bishop and his co-workers performed bone grafts, dual grafts were used in 175 with only 12 failures (7 per cent) Union took place in essentially the same length of time as the single onlay graft. Many of these grafts were carried out in unfavorable or difficult cases, with marked decalcification of the host bone or sclerosis of the bone or were associated with considerable soft tissue loss and scarring from gunshot wounds, as well as bone defects from one to five inches in length.

THE INLAY BONE GRAFT

The inlay and sliding inlay autogenous bone grafts, as devised by Albee, are more adaptable to the tibia than to any other location and especially to the upper third close to the joint. Albee and other surgeons, however advocate their use for other long bones as well.

To construct a sliding inlay graft parallel cuts are made on the longer fragment and extended across the fracture site onto the shorter fragment. The

portion of bone thus removed from the longer end is slid across the fracture into the trough on the short fragment For the inlay graft, a trough is made in the fractured bone and a graft of exact dimensions is removed from the tibia and inserted into the trough

These procedures are advantageous in that they are simple and comparatively easy of performance, and may be completed within a short time The disadvantage lies in the fact that a considerable portion of the circumference of the fragments, from which union must be secured, is removed If union fails to take place and the graft sequestrates, subsequent operations are rendered far more difficult by the remaining defect in the cortex of each fragment.

Sliding Inlay Graft

Technic (Albee) —After proper exposure of the fractured area, periosteal flaps are turned back from each side of a longitudinal incision over both fragments, and the ends of the bone are delivered freed of scar tissue and freshened

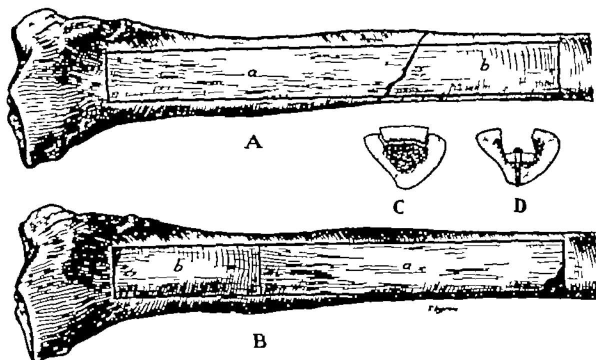


Fig. 451.—Sliding inlay graft (Albee) *A* Grafts cut on each fragment. *B* Grafts reversed, the longer segment placed across fracture site. *C*, Cross section of inlay graft. *D* Massive sliding graft (Buchanan-Wagner) similar to sliding inlay method, though graft is placed in medullary canal and fixed with metal screws.

with an osteotome motor burr, or saw The ends are then brought into normal alignment. Parallel saw cuts are next made, beginning as far proximally or distally on the longer fragment as possible, extending through the line of fracture, then a distance of three inches onto the shorter fragment. If the fracture is near the knee joint, the longer portion is taken from the distal fragment if near the ankle, the longer portion is removed from the upper fragment. With a cross-cut saw the parallel longitudinal cuts are joined at the upper and lower ends and the two grafts are removed. The longer graft, which should be six inches in length, if possible is passed across the line of fracture to the end of the cut on the short fragment. The shorter graft is placed into the space in the longer fragment. Fixation is secured by metal screws

Inlay Graft

If one of the smaller long bones, as the radius and ulna, is the site of fracture or if the bone is exceptionally atrophic, or a segment of bone of proper length for grafting cannot be secured because of other fractures above or below the following technic is preferable.

Technic (Albee).—The fragments are prepared as described above and placed in satisfactory alignment. With a twin bladed circular motor saw two cuts, three-eighths to three-fourths inch apart, are made completely through the cortex to the medullary canal. These cuts should extend from the fracture site onto each fragment a distance of three inches into normal bone. The cuts are connected transversely at both ends and the loose segment of bone is removed from each fragment thus creating a trough which extends three inches proximally and distally from the fracture site. The exact dimensions of the gutter are measured and a full thickness graft, wider than the gutter by one thickness of the saw blade, is removed from the tibia. By means of a mallet and bone set, the graft is firmly fitted into the gutter Stability is best enforced by means of metallic screws.

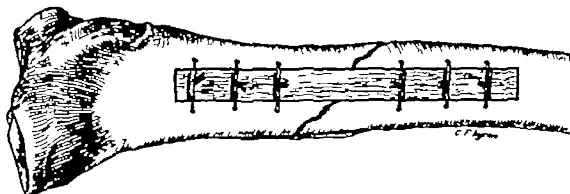




Fig. 451.—Inlay graft from opposite tibia (Albee) with various methods of fixing graft to fragments.

Diamond Inlay Graft

Technic (Gallie).—Gallie cuts a large diamond-shaped segment, four to five inches in length from both fragments, forming the wide central portion at the site of the fracture. A graft of slightly larger dimensions is taken from the tibia of the opposite leg and wedged tightly into the prepared space as the fracture is reduced

By this procedure union may take place but absolute fixation is difficult to maintain. The method also possesses other disadvantages common to all inlay grafts.

MASSIVE SLIDING GRAFT

Gill has devised a technic which embodies the use of a sliding graft of approximately one-half the circumference of the bone and from four to six inches

of its length Rustless steel screws are utilized for fixation Based on this same principle, Flanagan has revised and improved this technic for use in the tibia and femur Flanagan's procedure is particularly applicable to the bridging of bone defects (p 710) Armstrong employs a somewhat similar procedure, based on Gill's operation, which he calls the "split bone" technic.

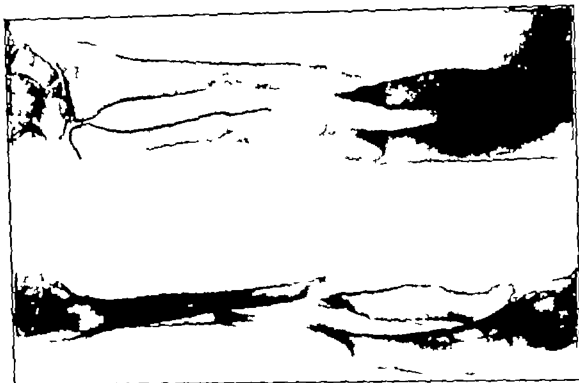


Fig. 433.—End result of massive sliding grafts, both bones of forearm, applied elsewhere grafts sequestrated. Loss of bone renders subsequent procedures difficult.

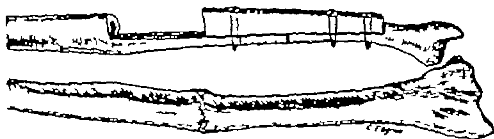


Fig. 434—Massive sliding graft (Gill)

Technic (Gill)—Through an incision along the length of the bone the periosteum of both fragments is split *longitudinally* With a motor saw, from one half to two-thirds of the thickness of each fragment is raised for a total distance of four inches, the major portion of the length being taken from the longer fragment. This long portion is placed across the fracture site in contact with both fragments and fastened with two or more metal or bone screws. If the two fragments are not in contact no effort is made to bring them into apposition entire reliance for union is placed upon the heavy bone plate

Buchanan described a technic for ununited fractures which we have employed in several cases when bone was not available from the opposite tibia for the onlay graft. In every case, solid union was obtained. Wagner has supplemented the procedure by fixing the graft in place with steel screws.

Technic (Buchanan Wagner) —The ends of the fragments are prepared and the grafts removed as described in the technic for the sliding graft. The longer segment is placed into the open medullary canal, bridging the fracture site, and its endosteal surface is apposed to the endosteal surface of the fragments posteriorly Fixation is secured by four to six steel or Vitallium self tapping screws (Fig 451*D*)

INTRAMEDULLARY BONE GRAFT

Campbell tried the intramedullary method of bone grafting in both fresh and ununited fractures. The many failures associated with this method led to the adoption of the onlay bone-graft technic. When union did take place, even in fresh fractures, consolidation was often so delayed that, generally function of the adjacent joints was permanently impaired. The undesirable effects on endosteal callus from a tight intramedullary apparatus has been previously discussed (p 367) As a rule therefore, the use of intramedullary bone pegs alone as a means of inducing union in ununited fractures of the shafts of long bones is not only to be deplored, but also condemned. The procedure was originally employed principally in the shaft of the femur We now limit its occasional application to the metacarpal and metatarsal bones, the trochanteric region, the neck of the humerus and the distal end of the radius, i.e., chiefly in metaphyseal regions Although the subsequent technics are given only for the shaft of the femur, the principles of the operation do not differ for other locations

The use of metallic intramedullary pins or rods, even in the treatment of ordinary nonunion of the shaft of the long bones, is not advisable. Considerably more must be known about the end results of medullary fixation with metallic pins before its indications are expanded.

Technic.—A five inch graft, three-eighths inch in width, is taken from the tibia and shaped to fit snugly into the medulla of the lower fragment. The fractured surfaces are then approximated, as much as possible of the protruding end of the graft being inserted into the medulla of the upper fragment. At the most, this is only one and one-half inches, as the soft tissues will not stretch sufficiently to permit the insertion of a longer portion. The extremity must be held very gently that no strain will be placed upon the graft otherwise, a fracture is inevitable and the purpose of the operation defeated. Alignment is maintained, but complete fixation is practically impossible.

Technic (Hoglund) —The ends of the fragments are exposed and freshened. By means of a round burr or curette, sclerotic bone plugs are removed from the medullary canal in each fragment. A bone graft of a width which corresponds to the diameter of the medullary canal is now cut from the shaft of the longer fragment at a distance of one inch from the fracture, leaving a complete ring of bone at the fractured end The end of the graft nearest the fracture is made into a point, while the other end is cut squarely across. With the fragments in satisfactory alignment the graft, its pointed end toward the fracture, is now forced into the medullary canal and across the line of fracture until each fragment contains one half the graft. Thus, the fracture will be held against lateral displacement by the intact ring at the fracture site If desired, the graft may be more securely fixed by screws.

Ryerson has modified the usual technic, believing that a short intramedullary graft does not provide leverage necessary to insure the desired stability, that a long one cannot be inserted by the methods described above, and further, that in the smaller bones the medullary cavity is not sufficiently large to admit an intramedullary graft of proper length He obviates these difficulties by combining the principles of the inlay onlay and intramedullary grafts

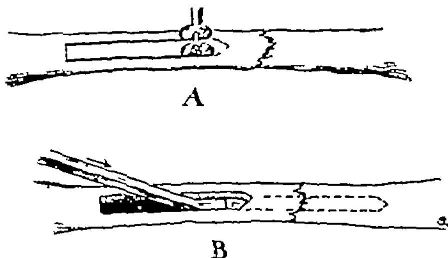


Fig. 455.—Intramedullary graft, technic of Hoglund. *A* Graft cut from one fragment, with pointed end adjacent to fracture site. *B* Graft forced into intramedullary canal and across fracture site, leaving continuity of bone intact adjacent to fracture on fragment from which graft was removed. (Redrawn from Hoglund, Emil J Surg. Gynec. Obst. 24: 243, 1917)

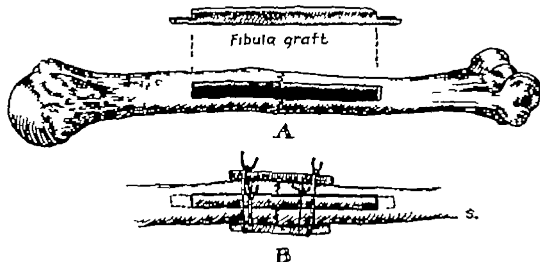


Fig. 456—Combined intramedullary and inlay graft (Ryerson) *A* Graft from fibula slightly longer than trough. *B* Extremities of graft introduced into medulla of each fragment, Segments removed in forming trough used as supplementary grafts. (Redrawn from Ryerson, Edwin W South. M. J 19: 512, 1926)

Technic (Ryerson)—A long slot is cut in both fragments, in a manner similar to that described for the Albee inlay procedure A hole is then drilled still farther along the shaft, beyond the slot into the medullary cavity of each fragment. A graft is removed from the fibula and fashioned to fit accurately into the slot with a one half inch prolongation of smaller size at each end. These ends are driven into the medullary canal at each end of the slot as the graft is applied. Strong chromic catgut ligatures are tied around the bones near the fracture. The pieces of bone removed in making the slots are laid on each side of the fracture site and similarly tied in place

OBLIQUE UNUNITED FRACTURES

Oblique fractures ordinarily unite rather readily unless muscle tissue is interposed, or contact between the fragments is lacking. If the fracture surfaces are short, the routine onlay graft is utilized If the surfaces are long efficient fixation and osteogenesis may be accomplished without the aid of a massive cortical graft.

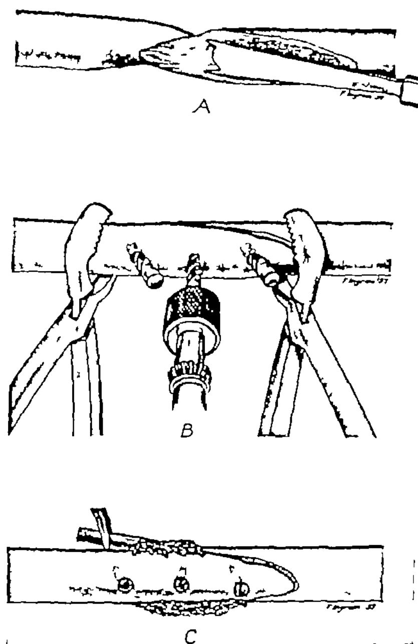


Fig 487—Technic for nonunion of oblique fractures. *A* Fractured surfaces freshened. *B* Fragments replaced in proper position, and traversed by drills. *C* Fixation secured by transfixion screws endosteum and cancellous bone packed about fracture site.

Technic.—The site of fracture is exposed, the periosteum being conserved intact so far as possible, and the tissue between the fragments is removed. After denudation of the fractured surfaces to practically normal bone, and clearance of the medullary canal both fragments are restored to anatomic alignment and

held by a bone clamp With a one-eighth inch drill point, two or three holes are then drilled across the oblique fracture surfaces at slightly divergent angles Screws of appropriate size are used to fix the fracture The normal osteogenic processes are facilitated by rather generous amounts of cavernous bone from the ilium packed about the line of the fracture

UNUNITED FRACTURES OF THE LONG BONES AND SPECIAL REGIONS

To avoid repetition the foregoing technics have been described for the treatment of ununited fractures in general Subsequent discussions will deal with the application of these methods to specific fractures.

UNUNITED FRACTURES OF THE METATARSAL BONES

Ununited fractures of the metatarsal bones are rather rare, usually resulting from a lack of apposition and contact of the fragments or in connection with some septic process which precluded union The nonunion is most often in the distal third

Technic.—The fracture is exposed by a dorsal incision After mobilization of the fragments, the ends are denuded and freshened by gentle bites with a rongeur This process should not be sufficiently extensive to produce undue shortening After reaming out the medullary canal the fragments are approximated and the fit checked for maximum contact. After subsequent minor readjustments of the fit fixation is maintained by an intramedullary bone peg or by an intramedullary wire as described for fresh fractures (p 380) Two catgut sutures are then passed around the bone proximal and distal to the fracture. Thin, flexible osteoperiosteal grafts, or segments of cancellous bone from the ilium are tied in place about the fracture site, so as to provide a flexible osteogenic envelopment of three-fourths of the circumference of the fracture

After Treatment.—Convalescent care follows essentially the same pattern as that described for fresh fractures of the metatarsal bones (p 381), except that weight bearing must not be allowed until six or eight weeks have elapsed, and then only if adequate callus or union is present.

UNUNITED FRACTURES OF THE INTERNAL MALLEOLUS

Even in efficiently treated Pott's fractures, the internal malleolus occasionally fails to unite. Usually malposition with the malleolus displaced forward is associated with nonunion There are three possibilities as to treatment (1) Conservative therapy in the form of an ankle corset scaphoid patch, inner heel wedge, or arch support, may be advisable if the fragment is small and the patient s occupation does not necessitate walking over rough ground. (2) If there is sclerosis of bone adjacent to the fracture site surfaces, considerable absorption of bone as to preclude an accurate fit and the proximal portion of the malleolus is sufficient to preserve the ankle mortise resection of the distal or ununited fragment is preferable to bone *grafting* (3) Briefly stated a bone-grafting procedure is indicated if neither of the above two procedures seems applicable

Resection of the Internal Malleolus—The skin is incised longitudinally for two inches over the internal malleolus The fascia and ligament are divided in line with the skin incision. The distal fragment is hulled out of the

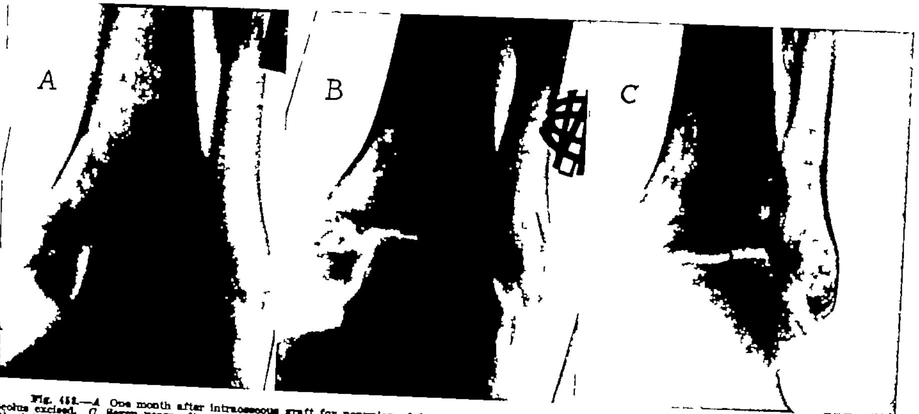


Fig. 451.—*A* One month after intraosseous graft for nonunion of fracture of internal malleolus. *B* Failure of grafting procedure. Internal malleolus excised. *C* Seven years after resection, ankle is stable though there are beginning mild arthritic changes. This is the maximum amount of the internal malleolus which can be removed if stability of the ankle is to be preserved.

ligament subperiosteally by sharp dissection, without interruption of its con tinuity in a transverse plane Care should be exercised to avoid cutting the posterior tibial tendon, or adjacent structures.

After Treatment.—Weight bearing may be begun three weeks postopera tively, with the ankle in a leather corset

Bone Graft.—An incision is made directly over the malleolus in line with its anterior border The bone is exposed by subperiosteal dissection over the an terior one half or two-thirds, and the fractured surface of each fragment is denuded. A bone peg two inches in length and slightly larger than a No. 19 drill hole is removed from the upper third of the tibia The fragments are then approximated. With a No 19 drill, a hole is next made through both fragments from below in an upward and lateral direction and the graft is driven tightly into this hole a steel driver or inlay being used for the purpose. Cavernous bone from the upper third of the tibia is packed about the line of fracture on the medial aspect in a manner which prevents contact between the chips and the ankle joint.

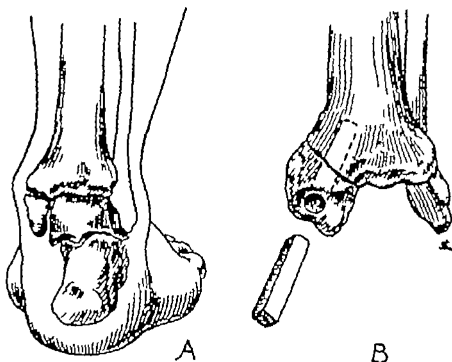


Fig 439.—*A* Ununited fracture of internal malleolus. *B* Fractured surfaces freshened, fracture reduced, and fragments held in place by autogenous bone peg.

A rustless steel screw may be utilized for fixation, although probably an autogenous graft is preferable

After Treatment.—The leg is placed in a walking cast from the toes to just below the knee as soon as the postoperative reaction has subsided, walking is permitted with the aid of crutches. After the fourth or fifth week the crutches may be discarded and full weight bearing begun. The cast is removed at the end of eight weeks. A leather ankle corset is then applied and a leather cork arch support is fitted in an orthopedic shoe and both are worn for a period of three months

UNUNITED FRACTURES OF THE TIBIA

Ununited fractures of the tibia are best treated by the onlay bone graft method. The graft is placed on the lateral surface of the tibia as far posteriorly



Fig. 460.—Nonunion following osteotomy failure to produce union by sliding inlay graft.

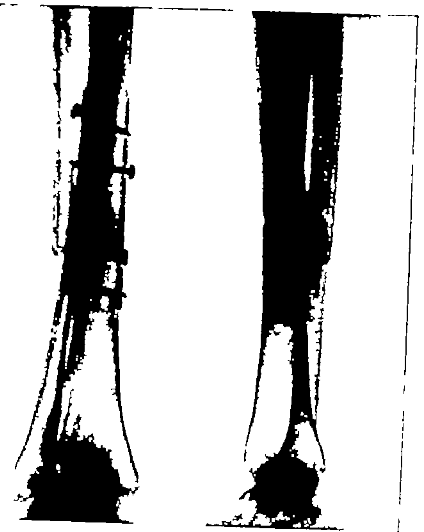


Fig. 461.—Same as Fig. 460 four years after dual onlay graft.



Fig. 482.—*A* Oblique comminuted fracture of upper third of tibia with fracture of tibial plateau. *B* Satisfactory restoration of fragments. *C* Fracture of shaft failed to unite treated by a single onlay graft.

as possible. When both tibiae are involved in an ununited fracture, an autogenous onlay bone graft on both bones is usually not practical. In this event, a homogenous graft from the bone bank, supplemented by fresh iliac bone is a satisfactory substitute. In lieu of this procedure, a sliding inlay graft, or a massive sliding graft may be utilized. The status of union or nonunion of the fibula is entirely disregarded. If malunion is present, however osteotomy through the fibula may be necessary before satisfactory alignment and apposition of the tibia are possible

After Treatment.—With the knee partially flexed a cast is applied from the groin to the toes, and a window is cut from just above the knee to the dorsum of the foot to allow for postoperative swelling. At eight weeks, the cast is removed and roentgenograms are made to determine the degree of union. If the roentgenogram shows evidence of beginning union and clinically the fracture site is solid, the extremity is placed in a walking cast from the groin to the toes, steel joints being incorporated at the knee with a drop ring catch to permit passive motion. Weight bearing with the aid of crutches is then gradually resumed. At three months postoperatively union has usually progressed sufficiently to warrant the application of a leather lacer brace with a drop ring catch at the knee The brace is generally discarded at six months.

UNUNITED FRACTURES OF THE PATELLA

In the future nonunion of a fracture of the patella will probably be relatively rare. In the presence of comminution, the fragments are excised, thereby eliminating the possibility of nonunion. Without comminution, internal fixation by wire sutures of the fresh fracture is eminently satisfactory so far as union is concerned

If the fragments are closely approximated, fibrous union may be compatible with function. Subsequent arthritic changes will be more or less proportionate to the incongruity of the articular surfaces of the patella. With separation of the fragments, or with comminution and nonunion, partial or total excision of the patella, as utilized for fresh fractures, is indicated. Plastic procedures to re-establish normal tension in the quadriceps mechanism may augment the routine procedures for the fresh fractures. In some cases, it may be necessary to lay generous fascial strips longitudinally between the quadriceps and patellar tendons, in order to restore a strong continuity If the quadriceps tendon is under undue tension and tends to distract the line of repair a Bunnell pull-out suture is inserted well proximal to the transverse incision through the quadriceps tendon The ends of the pull-out suture are run off through the skin distally and slight traction is maintained by means of a Spanish windlass for a period of two to three weeks

UNUNITED FRACTURES OF THE FEMUR

Ununited Supracondylar Fractures of the Femur

Fortunately ununited fractures of the lower end of the femur are exceedingly rare. When nonunion does occur in this region, union is secured with difficulty Nonunion of a long oblique fracture through the metaphyseal region is treated as suggested on p 634.

In nonunion of transverse or short oblique fractures just above the condyle, either of two types of procedures may be carried out as follows (1) In relatively recent fractures in young individuals, a right angle blade plate may be utilized for fixation, as described for fresh fractures The metallic fixation is supplemented by a generous number of iliac grafts placed about the fracture (2) If the condyle is too osteoporotic for adequate fixation with a blade plate a dual onlay bone graft applied in much the same manner as described for ununited Colles fractures (p 727), may be employed In the majority of cases by the time such procedures become necessary motion of the joint is reduced to only a few degrees by a fibrous intra articular and extra articular ankylosis. Osteoporosis of the condyles is so far advanced that only a shell of the original condyle remains

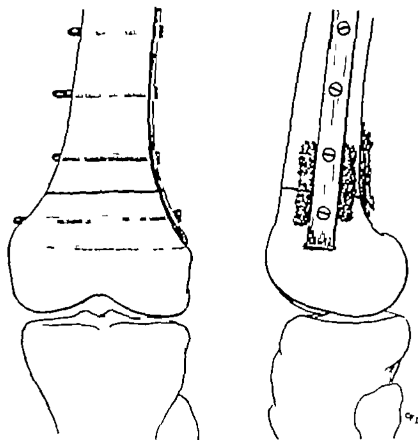


Fig. 441.—In nonunion of relatively recent origin, fracture surfaces are denuded and fixed in place by right-angle blade plate. Osteogenesis promoted by a generous number of iliac grafts placed about fracture.

Technic.—A six inch longitudinal incision of sufficient length to give access to the condyles of the femur and to the distal four inches of the shaft is made over the lateral aspect of the lower end of the femur The fractured surfaces are denuded of scar tissue, and properly aligned. A right angle blade plate of proper dimensions to penetrate both cortices of the condyles of the femur is inserted and the stability of the fixation checked. If adequate, the longitudinal portion of the blade is fixed to the shaft of the femur with an appropriate number of screws. A generous amount of cavernous bones from the ilium is packed about the entire circumference of the fracture site During the above procedure an attempt should be made to avoid violation of the suprapatellar pouch in many instances, however, this will not be possible

The technic described above may be reinforced by a graft, the proximal portion being applied as an onlay the distal portion is an intra-osseous graft forced into the condyle To minimize the amount of foreign material, the graft, blade plate and cortices of the shaft may be transfixed by the same screws, thus producing the same effect as a dual graft (p 625)

When the procedures described above have failed, or there is a probability of failure the following operation, which entails fusion of the knee offers a better prospect of solid union.

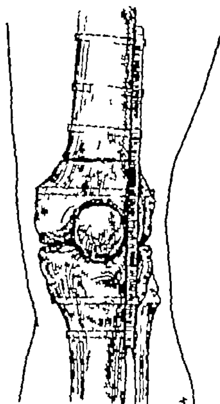


Fig. 464.—Nonunion of supracondylar fracture of femur of long duration eggshell replica of original condyle precludes adequate fixation. Since ankylosis is relatively well established, technic for establishing union may necessitate extension of graft across knee joint.

Technic.—The incision is begun over the lateral aspect of the tibia three inches below the knee, extended across the anterolateral aspect of the knee, and up the lateral aspect of the thigh for a distance of five inches. The *vastus lateralis* muscle is retracted laterally and the periosteum is incised and elevated over one-third of the lateral surface of the femur After all scar tissue is dissected from the line of fracture, the ends of the bones are freshened The knee joint is then opened, and the articular cartilage is excised from the surfaces of the tibia, femur and patella With the fragments in satisfactory alignment, a groove is made in the external condyles of the femur and tibia, and a flat surface created on the anterolateral aspect of the shafts of both bones. The graft is then prepared as an onlay placed on these flat surfaces, bridging the joint, and fixed with six metallic screws of appropriate length. The fused knee joint may be reinforced by crossed Knowles pins. Cancellous grafts should be applied to promote osteogenesis at both the fracture line and the knee joint

After Treatment.—The extremity is immobilized in a single spica cast from above the crest of the ilium to the toes, the knee and hip being held in

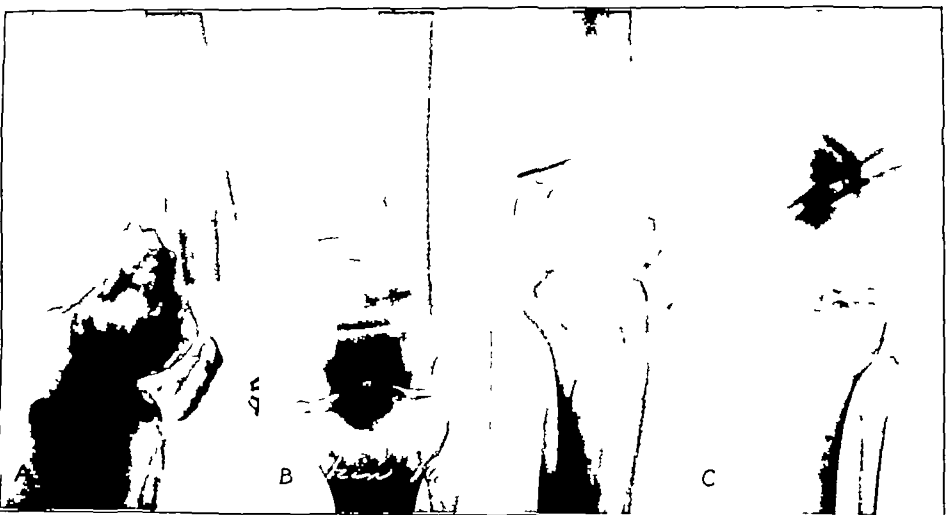


Fig. 466.—*A*, Nonunion of compound infected supracondylar fracture. *B* After operation as described for oblique fractures. Four autogenous bone pegs used for fixation; failure. *C* Solid union after sliding graft from tibia on same side bridging knee joint and fracture site. Stainless steel nails across fracture for supplementary fixation.

complete extension. A window is usually cut from just below the groin to the ankle, to allow for postoperative swelling. This cast is removed at the end of eight weeks and roentgenograms are made to determine the progress of union; if satisfactory, the spica cast is replaced by a walking cast of similar length, and weight-bearing is gradually resumed. If union is not sufficiently solid, another single spica cast is applied and weight bearing is delayed for a month. At three months, a Thomas caliper brace, with a leather lacer corset extending from the groin to the ankle, is fitted and worn for a period of at least three additional months.

Ununited Fractures of the Shaft of the Femur

Ununited fractures of the shaft of the femur at any point below the subtrochanteric region or above the supracondylar region are best treated by an onlay bone graft (p. 619). A graft one inch in width and six to eight inches



Fig. 466.—Nonunion of femur. Fragments solidly united in excellent position twenty-eight months after onlay graft. Graft incorporated in callus.

in length is applied to the lateral or anterolateral surface of the bone with six metallic screws. In the middle and upper thirds of the femur there is always a tendency to lateral and anterior bowing, with displacement of the proximal end of the graft. For added strength in this region, or in any case wherein a

single onlay graft does not provide sufficient stability, the dual onlay graft is applicable Or, a plate and graft may be combined

After Treatment—With the knee and hip in 150 degrees' flexion, a cast is applied from the nipple line to the toes and to the knee on the unaffected side At eight weeks postoperatively, the cast is replaced by a walking spica cast extending from the nipple line to the toes joints being incorporated at the knee to permit passive motion After four weeks, if union is adequate a reinforced leather lacer corset which duplicates the cast, with a rigid joint at the hip and a drop ring catch at the knee is fitted Four weeks later, free motion is allowed in these joints. The brace should not be discarded entirely until six months after operation

Ununited Subtrochanteric Fractures

Ununited fractures of the subtrochanteric region although rather rare, warrant description in that the ordinary types of grafts will not conform to the contour of the bone and do not provide adequate fixation There is always such a pronounced tendency toward bowing in this region that the use of a graft alone is inadequate A blade plate or other apparatus, as utilized for intertrochanteric fractures, provides adequate fixation The normal reparative processes are facilitated by the use of both cortical and cancellous grafts.

If deformity is excessive a period of preoperative skeletal traction to regain length and proper alignment materially reduces the magnitude of the operation At operation the patient should be placed on a fracture table in the supine position, with the affected extremity draped into the sterile field to allow manipulation of the extremity should this become necessary

Technic.—The upper third of the shaft of the femur and the lateral and anterior aspects of the greater trochanter are exposed through a lateral incision seven inches in length (p 179) The vastus lateralis muscle is stripped subperiosteally from the anterior aspect of the shaft of the femur and held in a medial position by means of a Blount anvil retractor The latter is also of immeasurable benefit later in the operation in producing pressure and counter pressure on the bone. Considerable stripping and dissection is usually necessary before both fragments are thoroughly mobilized. The ends of the fragments are denuded of scar tissue and freshened and the medullary canals are reamed out. The ends of the fragments are shaped to provide maximum contact and a stable reduction. Long oblique fractures are handled as described on p 634. A Blount blade plate of appropriate length is next inserted in the manner described for fresh trochanteric fractures (p 426) With the foot of the affected extremity tied to the sterilly draped foot piece traction is exerted and the fragments are manipulated into proper position and alignment with the shaft portion of the blade. Proper rotary relationships are checked, and screws of appropriate length and size are then inserted for fixation.

While this procedure is in progress, a full thickness cortical graft is excised from the opposite tibia. The cortical graft is laid on the anterior surface of the shaft without screw or tie fixation Generous amounts of cancellous grafts are placed around the entire circumference of the fracture iliac bone is par

ticularly efficacious The grafts are maintained in situ by a careful suture of the vastus lateralis muscle.

After Treatment.—(See p 645)

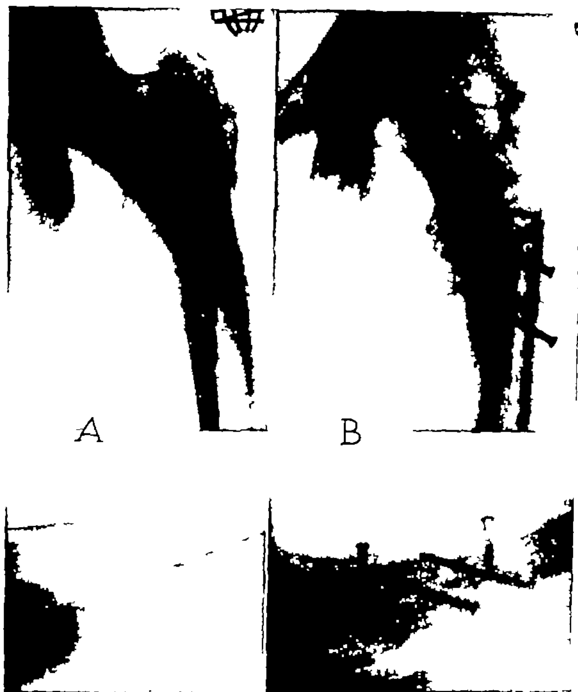


Fig. 457—*A* As in this case, oblique fractures of femur usually fail to unite only from a total lack of contact of fragments. *B* Eight weeks after denudation of fracture surfaces, fixation with two transfixion screws and an onlay bone graft to anterior surface of femur

Ununited Peritrochanteric and Intertrochanteric Fractures of the Femur

Ununited fractures of the femur in this region are usually the result of poor approximation or lack of approximation from inefficient or no treatment.

As a rule, a rather marked degree of shortening associated with coxa vara deformity is present Since circulation is adequate *the ends of the fragments* are usually absorbed to only a moderate degree.

The majority of these patients being elderly, procedures of considerable magnitude are inappropriate With proper approximation and fixation the normal osteogenic powers are with a few exceptions, adequate Consequently, extensive bone grafting procedures are unnecessary In the presence of a rather marked degree of coxa vara deformity, a short period of skeletal traction to regain length minimizes the surgical procedure The patient is placed on the fracture table for the operation with the legs tied to the foot pieces in the same manner as described for the insertion of a Smith Petersen nail for a central fracture of the neck of the femur (p 435)

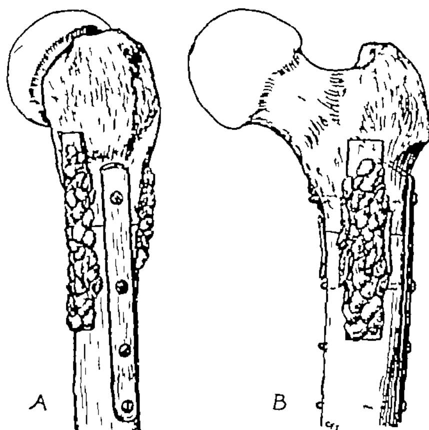


Fig. 442.—Ununited subtrochanteric fractures are best fixed by a metal plate, to counteract pronounced tendency toward bowing in this region. Cortical and cancellous grafts are adequate to reinforce normal reparative processes.

Technic.—The lateral portion of the neck of the femur, the fracture site, the trochanter and the upper four or five inches of the shaft of the femur are exposed through a curved lateral incision between the tensor fascia femoris and the gluteus medius muscles (p 150) Fibrous tissue is excised from the fracture surfaces, the fragments are freshened and the fracture is reduced. Internal fixation is effected by the use of a blade plate or other apparatus, as for fresh intertrochanteric fractures (p 426) Defects at the fracture site are packed with cancellous bone from the adjacent ilium. Prior to closure of the wound, final roentgenograms should be made in both the anteroposterior and lateral views, to confirm the position and approximation of the fragments.

After Treatment.—If the outer fragment or trochanter is osteoporotic and metallic fixation seems inadequate, some type of skeletal traction to the lower end of the femur, with the leg in balanced traction, should be maintained for at least three or four weeks. During this time, knee exercises and measures to preserve muscle tone may be carried out. In a few peritrochanteric fractures, a body cast incorporating a Hoke-Martin traction apparatus may be necessary Ordinarily all immobilization and restraint is removed after eight weeks. Three months postoperatively walking is permitted with crutches. Full weight-bearing is not resumed until roentgenograms reveal sufficient union to preclude recurrence of the coxa vara deformity

UNUNITED FRACTURES OF THE NECK OF THE FEMUR

Pathologically and physiologically, there is such a wide difference between complete central or intracapsular fractures of the neck of the femur and those of the long bones that, under no circumstances should they be considered together Nonunion occurs more frequently in the neck of the femur than in any other part of the skeletal system. Sir Astley Cooper and a majority of the older surgeons believed this fracture united only by fibrous tissue, and even since the year 1900 one can find statements to the effect that osseous union does not take place.

A great contribution to the treatment of fractures of the neck of the femur was the abduction treatment described by Royal Whitman in 1896 This procedure was soon accepted by the majority of orthopedic surgeons, as Whitman and others produced conclusive evidence of securing osseous union in many cases. For a time, indeed, failures were believed to be of rare incidence. As the years passed, however the measure was found to be successful in only 50 per cent of patients thus leaving a rather large number in whom the fracture failed to unite

The end results of treatment by internal fixation would suggest that central fractures of the neck of the femur are no longer unsolved problems. It is safe to say however that the problem may be considered as only partially solved. Boyd and George, in a review of 176 fractures of the neck of the femur which were followed for one year or longer found union in 85 per cent and nonunion in 15 per cent. In 60 per cent of the nonunions, *aseptic necrosis of the head of* the femur was present 32.6 of the patients who obtained union exhibited similar changes or arthritic changes. Consequently the approach in the future will place emphasis upon the prevention of aseptic necrosis rather than upon the problem of nonunion

Even with efficient treatment, one can of course always anticipate a sufficient number of nonunions to warrant thoughtful study Factors which may have a bearing on the high incidence of nonunion of fractures in this region are discussed briefly

1 Since an adequate blood supply is the most important requisite to the production of callus, retarded or failure of reestablishment of vascularity across the fracture site must play a major role in nonunion Wolcott has demonstrated an anastomosis between the arteries of the ligamentum teres the head and the posterior capsule. The majority of complete fractures of the neck of the femur occur through Ward s triangle, which is a weak area bounded by trabecular lines

of pressure and tension, with advancing age the bone in this triangle is gradually replaced by fat When the femoral neck is fractured through this region, the anastomosis of the vessels is interrupted and the femoral head may be deprived of the majority of its blood supply from the nutrient and capsular arteries. The vessel in the ligamentum teres usually is incapable of maintaining the viability of the head unassisted in elderly individuals, particularly the

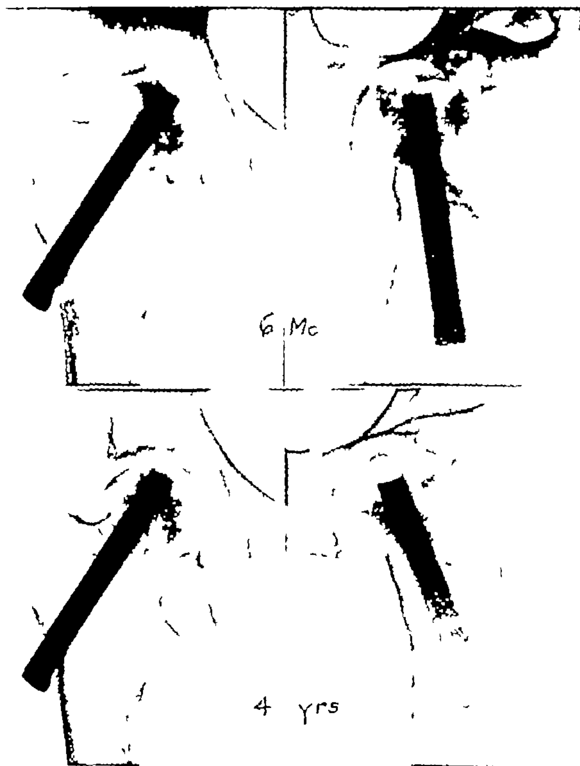


Fig 469 —At six months patient complained of pain in hip, and roentgenograms would seem to verify an impending nonunion. Premature removal of internal fixation would probably have been deciding factor between union and nonunion. At four years, patient has an excellent hip.

lumen of the vessel may be decreased in size or occluded These conditions may be largely responsible for the slow process of healing of this particular fracture

In our series of cases the percentage of aviable heads following the old Whitman method of treatment, and the present treatment by internal fixation, is essentially the same This would suggest that the form of therapy probably had little to do with the survival of the head It would seem that, in most cases, the die is cast at the time of the fracture as to whether the head will or will not remain viable Interruption of the capsular vessels posteriorly probably plays the predominant role. In a few border line cases, the head of the femur may survive from prompt and efficient treatment, due to an ingress of capillaries across the fracture site.

2. An inaccurate reduction or no reduction at all is undoubtedly responsible for nonunion in many cases. Callus is derived chiefly from the distal fragment, and union occurs, not from periosteal proliferation but from endosteal callus. The cambium layer is absent from the soft tissue coverings of the neck. A perusal of our cases suggests that inaccurate reduction is a less important factor than inadequate fixation. Union may be expected to take place with less than an anatomic reduction provided internal fixation holds firm.

3 Improper nailing followed by a loss of fixation is an important factor in the production of nonunion. A constant shearing action at the fracture site interrupts the normal process of repair and revascularization With proper nailing the shearing action at the fracture site is eliminated and is probably not a factor in nonunion, even in Pauwel's type III fractures.

Pain in the hip three or four months after internal fixation, is usually due to lack of union Except for protrusion through the head or out into the soft tissues adjacent to the trochanter the nail is not responsible for any symptoms. Premature removal of internal fixation does not relieve the pain and may be the deciding factor between union and nonunion.

4 Inefficient after treatment, wherein functional use is permitted before nature has had time to consolidate the new bone firmly may lead to impairment and perhaps disintegration of the reparative process

5 The capsule may be torn and caught between the fragments.

Santos, Phemister Sherman and others, have reported the pathologic and reparative processes which take place in the head. When the living head unites and function is increased, the structure of the head and neck is gradually restored to normal. When the living head fails to unite, atrophy may progress until only a small portion remains When the dead head unites, the entire head may be gradually replaced by new bone from the distal fragment or the head may be only partially replaced, the remaining portion being a sequestrum In the latter event, the globular contour of the head becomes incongruous. When the dead head fails to unite, its size usually is diminished by a process of erosion and absorption. Subsequently however the structures may be invaded by new bone until entirely restored and the appearance approaches that of a living head and the surrounding bone

Theoretically it is possible to determine from the roentgenograms the status of viability of the head of the femur If the head retains its blood supply it should undergo the same degree of atrophy of disuse as the adjacent structures. If devoid of blood supply it should retain its original density in contrast

to the osteoporosis of the surrounding structures In cases of long standing the head may present a mottled appearance, suggesting the replacement of some of the areas of necrosis by new or viable bone, the mesial and superior portions of the head being the last to be transformed, should appear more dense than the remainder of the head This process of creeping substitution, according to Phemister may require from one and one-half to three years If weight bearing is begun before replacement is complete, the head will probably collapse and degenerative changes will take place on both sides of the joint

The roentgenogram does not reveal the changes in the cartilage In general the degenerative changes in the articular cartilage conform more or less to the areas of viable and nonviable bone in the head of the femur In any case if the blood supply does not reach the bone adjacent to the cartilage within several months after the fracture, the articular cartilage may be expected to degenerate completely and eventually to be replaced by fibrous tissue or fibro-cartilage, or even the bare bone may remain exposed

Although creeping substitution entirely replaces old bone with new, the anatomy is hardly normal. Replacement is rather irregular relatively good bone being interspersed with rather poor areas and cavities filled with a fatty substance. The bone structure in association with the degenerative changes in the articular cartilage eventually leads to arthritis.

Nonunion not only takes place more often but is reached at a much earlier period in central or intracapsular fractures of the neck of the femur than in any other location. Following efficient treatment with internal fixation the question as to when a fresh fracture graduates from an acute stage into a state of delayed or nonunion is primarily an academic one We have observed fractures which united as late as one year after a nailing procedure. Frequently, however at six months or even earlier one may be relatively safe in a prediction that a fracture will proceed to a nonunion The converse of this statement is not necessarily true. One year is ordinarily a minimum period in which to ascertain definitely the presence of a union, and two years to determine the status of the viability of the head. In poorly treated cases one may institute measures for nonunion as early as six weeks following the fracture

After the fresh fracture, the amount of absorption of the neck the degenerative changes in the head of the femur and the arthritic changes *ordinarily* increase with the lapse of time. Thus, the prospect of securing even a fairly accurate anatomic restoration becomes less favorable as nonunion continues

Considerations Preliminary to Surgery

Ununited fractures of the neck of the femur present a condition which renders the patient a more or less permanent invalid unless surgical treatment is undertaken. In the presence of a strong fibrous union walking with a decided limp and some degree of pain is possible though the patient's endurance is poor The majority of patients require the use of crutches for support Such a condition however, can no longer be described as hopeless or insurmountable by surgery An operation for this condition should offer a 60 to 75 per cent chance that the patient will be relieved of his pain with sufficient stability for ordinary weight-bearing, and a fair range of motion To accomplish this, a firm bony support must be provided to some portion of the upper extremity of the femur

The selection of the proper method of treatment is often difficult. An error in judgment may not be revealed until the test of time over a period of two or three years reveals a progressive aseptic necrosis of the head of the femur associated with marked arthritic changes. If the exact status of viability or *nonviability of the head of the femur could be determined early the indications* for various types of procedures would be materially simplified. This difficulty is encountered, particularly, in ununited fractures that are of less than one year's duration. In cases of questionable viability it is probably preferable to utilize reconstruction methods that do not require a viable head.

Prior to operation all of the following factors must be taken into consideration, the applicability of various surgical procedures in relation to these factors will be discussed in detail.

Age and Physical Status of the Patient.—Chronological age and physiologic age do not necessarily coincide. Suffice to say that the majority of these patients will be over 60 years of age and consequently a large number will present a relatively poor surgical risk. Not infrequently they exhibit manifestations of disease of the cardiovascular system and kidneys, and signs of mental deterioration. For these reasons, they are not candidates for the more shocking and lengthy surgical procedures. In patients who are poor surgical risks, we have frequently utilized the simpler surgical procedures which do not require postoperative immobilization or a long period of recumbency in preference to more extensive surgery which might produce a better mechanical hip. The improvement in preoperative and postoperative care of geriatric patients has undoubtedly extended the use of some of the more formidable procedures. The fact remains that the older the physiologic age of the patient, the more difficulties will be encountered both during and after surgery.

Status of the Head of the Femur.—A study of serial roentgenograms dating from the original fracture to the time of an established nonunion are of immeasurable benefit in determining the viability or nonviability of the head. On this point alone rests many major decisions as to the proper surgical procedures. Sections of bone removed from the heads of femurs at the operating table will reveal that preoperative roentgenograms are not infallible in this regard. Consequently one should not undertake an operation with a preconceived idea as to the vascularity or avascularity of the head particularly in the questionable cases.

At operation, to prove the viability of the head, the fracture surface is denuded until a uniformly bleeding cancellous surface is presented. At the opposite extreme, nonviability a *pithy hard, dense, yellow or white* area of cancellous bone which does not bleed, is found.

In 176 patients with fresh fractures of the neck of the femur who were followed for one year or longer the roentgenograms revealed that of the 15 per cent who had nonunion, the head was aviable in 60 per cent. Of the remaining 40 per cent in whom the head was supposedly viable, at least one-fourth may be expected to return, from one to two years following surgery for nonunion, with rather marked arthritic changes and scattered evidence of aseptic necrosis.

Other factors which enter into the surgical consideration and render the patient unsuitable for certain types of operations are (1) the presence of ar

thritic changes, (2) degeneration of the articular cartilage, (3) a lack of mobility of the head of the femur in the acetabulum, and (4) a small, atrophic, osteoporotic head

Status of the Neck of the Femur—Some degree of absorption of the neck of the femur takes place in every case of nonunion The exact factors which vary the amount of the absorption are not too well understood. In some cases, the neck of the femur is absorbed almost completely and in a relatively rapid manner In others, the length of the neck may be fairly well preserved and remain so for months after a nonunion is well established Certainly, the best anatomic results are secured in patients in whom the neck has remained relatively normal and without extreme upward displacement and shortening Excellent functional results from various operations are possible, however, even after absorption of the neck has become extensive.

In the presence of pronounced shortening of the extremity and rather advanced absorption of the neck of the femur, any of the reconstruction procedures are more difficult, and some are contraindicated. The muscles across the joint may be so contracted that it may be difficult or impossible to regain normal length, or to restore even an approximately normal anatomy Certain operations are predicated upon the reducibility of the remnant of the neck to the head. Although extreme osteoporosis of the trochanter and neck does not necessarily contraindicate any procedure it certainly affects adversely the efficiency of those which incorporate internal fixation.

Duration of Nonunion.—The duration of a nonunion is not necessarily the exact indication or contraindication for any operation The most favorable time to secure the highest percentage of results from any type of reconstruction is just as soon as the status of a nonunion has been determined. Many of the mechanical and physiologic factors which render a patient unsuitable for certain procedures may as a rule be expected to increase with time

OPERATIVE TECHNICS

The surgical procedures applicable to ununited fractures of the neck of the femur may be grouped into four general classes (1) osteosynthesis, (2) reconstruction, (3) osteotomy, (4) arthrodesis. In addition, the principles of two or more of these general classes might be combined.

The term "osteosynthesis is herein used to include any *operation* whose *prime feature* is the fixation of a viable head to the neck or trochanter The term reconstruction operation infers a procedure wherein the head of the femur is removed and a skeletal support is provided by insertion of the remnant of the neck or trochanter into the acetabulum "Osteotomy" is that group of operations wherein the femur is divided near the lesser trochanter and shifted to provide a more direct line of weight-bearing beneath the head of the femur The term arthrodesis is self-explanatory

Obviously, this grouping of operations is purely for simplification of discussion For example, in an osteotomy if the head is impaled by a pin, one can say that an osteosynthesis has been carried out, though the prime feature of the procedure is the osteotomy, not the *osteosynthesis.* Some Brackett operations mechanically fulfill the definition for *osteotomy* though the procedure is carried out quite differently from the ordinary osteotomy

OSTEOSYNTHESIS FOR UNUNITED FRACTURES OF THE NECK OF THE FEMUR

Operations classified under this heading have much in common surgery entails the preservation of the head of the femur as an articulating unit, and an attempt is made to reconstruct normal anatomy and procure union in so far as the mechanical and physiologic status of the hip will allow All procedures are designed to induce union between the head of the femur and a remodeled neck or trochanter

The optimum prerequisites for this group of operations are as follows little or no absorption of the neck of the femur a viable, freely movable head normal density of both fragments and a strong fibrous union with relatively little upward displacement of the distal fragment

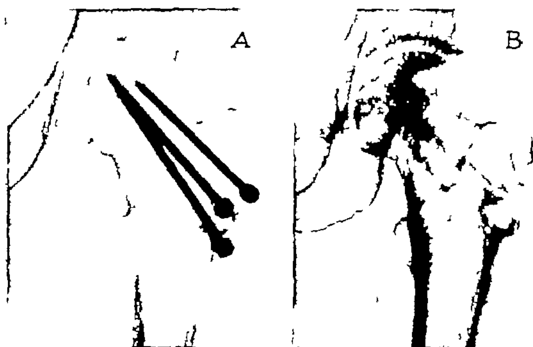


Fig 470—If nonunion is of relatively recent origin, the head and neck of femur are likely to be well preserved and suitable for osteosynthesis. *A* Six months postoperative. *B* Four and one-half years postoperative.

Factors which render the patient unsuitable for these procedures are as follows nonviable head excessive osteoporosis of all of the structures about the hip joint, partial ankylosis of the head, extreme upward displacement of the distal fragment, a small atrophic head, and marked absorption of the neck of the femur (the exceptions for the Brackett operation are described below)

The types of osteosynthesis are as follows

- Extra articular osteosynthesis
  - Metallic internal fixation
  - Bone-graft operation (Henderson)
  - Metallic internal fixation combined with iliac or other types of grafts
- Intra-articular osteosynthesis
  - All of the procedures listed under extra-articular osteosynthesis
  - Technic (Dickson)
- Brackett operation

Henderson has laid down some satisfactory rules to guide one in the selection of open versus closed osteosynthesis. By the closed method grafts or metallic fixations are inserted under roentgenographic control, in much the same manner as for fresh fractures of the neck of the femur. By the open procedure, the same technic is carried out though the fracture site is actually exposed, fibrous tissue is removed from between the fragments, and the ends are freshened and fitted as accurately as possible prior to the insertion of the bone graft or metallic fixation.

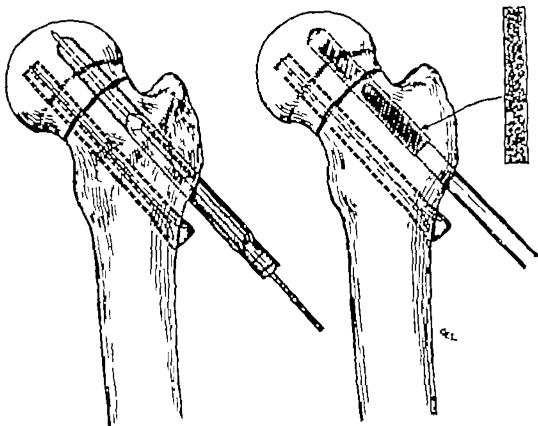


Fig. 471.—Closed osteosynthesis with metallic internal fixation and iliac graft. Nail inserted by same technic as for fresh fracture. Tunnel created for reception of iliac graft by cannulated Henderson reamer.

If the closed or extra-articular technic is to be used, all shortening must be overcome prior to operation, and immediate preoperative roentgenograms must show that the femoral head and neck are in relatively normal alignment and position. Henderson points out that if the status of the nonunion is a true pseudarthrosis, i.e., no fibrous union, blind insertion of the graft without freshening of the fragments will probably fail. When a graft traverses a typical pseudarthrosis, nutrition and new formation of bone across the fracture site will not be adequate and the graft will gradually disintegrate. If the neck has been extensively absorbed, a great deal of laxity at the fracture is likely and, consequently, very little fibrous union. Laxity can be determined preoperatively by anteroposterior roentgenograms made while traction is exerted on the extremity.

Undoubtedly, osteosynthesis produces the most satisfactory functional result of all of the procedures utilized for ununited fractures of the neck of the femur. Unfortunately, only a relatively small group of ununited fractures present the necessary requisites for osteosynthesis.



FIG. 472.—Union after osteosynthesis result excellent at one year, function decreasing with progressive arthritic changes and necrosis of head. A Four months. B Seven months. C Two years.

Closed Osteosynthesis

Until the elapse of six weeks nailing of the hip by the routine measures described for fresh fractures of the neck of the femur (p 435) is permissible After six weeks, a bone graft, preferably in combination with metallic fixation is better than the use of an inert substance alone

Closed Osteosynthesis by a Fibular Graft (Henderson) —The patient is placed on a fracture table in the same manner as described for internal fixation of fresh fractures of the neck of the femur (p 96) Through a longitudinal lateral incision, the upper portion of the shaft and lateral aspect of the trochanter are exposed (p 179 and p 150) A Kirschner wire is then inserted through the center of the trochanter neck and head, and its position is verified by roentgenograms in two planes If the wire has been satisfactorily placed, three cannulated reamers of different sizes are used in series to prepare a tunnel or channel for the reception of a graft from the fibula The last reamer used is a little smaller than the diameter of the fibular graft. Since the reamers are cannulated and threaded over the guide pin there is no deviation in direction. A graft of appropriate length (three to four inches) is removed from the middle half of the fibula To promote the infiltration of blood vessels into the graft all soft tissue is removed and, with a chisel the cortex is roughened in a fish scale manner The medullary canal of the graft is then threaded over the guide pin, and driven into the trochanter, neck, and head.

After Treatment.—It is essential that firm adequate postoperative fixation by means of a double spica plaster cast be enforced until bony union is apparently certain. This is a minimum of three months. Subsequent fixation and treatment depends upon the progress of the union. Unsupported weight bearing is rarely permissible under six months.

Roentgenograms should be made at intervals of two months for a period of at least one year Union should not be considered complete until new trabeculae cross the line of fracture this must not be confused with overlapping of the old trabeculae.

Henderson reports that of 67 of 77 patients who could be traced, 69 per cent obtained union.

Closed Osteosynthesis With Metallic Internal Fixation and Iliac Grafts.—The preliminary measures are carried out as described above in the Henderson technic. Two guide pins are inserted through the trochanter and neck, and into the head in a parallel direction and approximately three fourths to one inch apart. Checkup roentgenograms in the lateral view should show the two pins overlapped and in the center of the neck and head. In the anteroposterior view the distal pin should parallel and be just above the lower border of the neck. The proximal pin should be parallel and just below the upper border of the neck. A Smith Petersen nail of appropriate length is threaded over the lower guide pin and driven into place, and the lower guide pin is removed A cannulated Henderson reamer is then threaded over the proximal wire and a tunnel drilled through the trochanter neck, and into the upper portion of the head The guide pin is removed. A graft is next taken from the middle third of the ilium. The graft should consist of both cortices and the intermediate cancellous bone, and should be slightly smaller than the tunnel. Even with the

two cortices intact, the graft is rather fragile and is inserted purely for osteogenic reasons. The graft is placed in the tunnel and tapped across the fracture site into the head, or if preferred, the tunnel may be packed with small segments of cancellous bone. Cancellous bone should extend throughout the entire length of the tunnel, thereby bridging the gap from the cancellous bone of the head to the cancellous bone of the trochanter

After Treatment—Essentially the same pattern is followed as that used for fresh fractures of the neck of the femur Full weight bearing is not allowed until union is definitely established clinically and by roentgenograms.

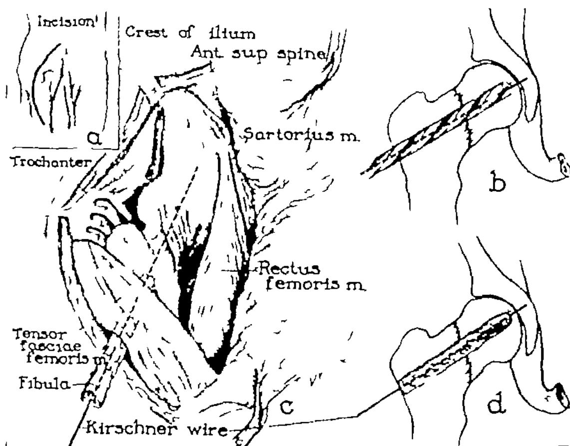


Fig. 473—Henderson technic of open osteosynthesis. *a*, Joint exposed through curved lateral incision. Before osteosynthesis is performed, fracture site is exposed, fibrous tissue removed from ends of fragments, and head and neck are accurately fitted together *b* Guide pin inserted in proper position cannulated reamer creates tunnel for reception of graft. *c* and *d*, Fibular graft driven into place over guide pin. (From Henderson, M. S., J Bone & Joint Surg. 22: 97 1940.)

Open Osteosynthesis

If the ununited fracture is of more than three or four months duration, open or intra-articular types of osteosyntheses are usually preferable to the closed methods. The technics described above for extra-articular osteosynthesis are applied, with the following exceptions a curved lateral incision (p 150) between the tensor fascia femoris and gluteus medius muscles, or variations of the anterior iliofemoral incision (p 149) are utilized to expose the hip joint, the lateral aspect of the trochanter and upper portion of the shaft of the femur Before the osteosynthesis is performed, the fracture site is exposed and the fibrous tissue removed from the ends of the fragments One may thus gain an

accurate idea as to the viability of the head The cancellous surface of the head of the bone should present a uniformly bleeding surface The ends of the fragments having been freshened, the neck and head are accurately fitted together The remainder of the technic is carried out as described above

J A Dickson has described an original type of intra-articular bone grafting which is now a part of his osteotomy-osteosynthesis technic There are occasions, however, when this technic may be utilized with metallic fixation, or in combination with other procedures

Technic (Dickson)—The fracture is reduced and internal fixation inserted. The anterior aspect of the hip joint is then exposed and a rectangular window is removed from the anterior surface of the neck of the femur adjacent to the fracture site With a curette fibrous tissue is excised from the fracture site and a cavity created in the cancellous portion of the head of the femur Cancellous bone from the ilium is then packed into the excavated head across the fracture site, and into the neck of the femur The rectangular window is replaced and held in place by suture of the capsule (Fig 491, *K*)

Brackett Operation

The popularity of the Brackett operation has increased during the past few years under the impetus of articles by Henderson, Magnuson and Ghormley and Rowe This type of operation is applicable to a large group of patients who fail to meet the rather rigid and exacting requirements for the osteosyntheses listed above It is to be presumed that their general condition and potentialities for further usefulness warrant an attempt to restore maximum function commensurate with the residual mechanical and physiologic status of the hip joint. The indications for the Brackett operation, as we understand them are essentially those for other types of osteosynthesis, with this *exception* if the neck of the femur has been absorbed sufficiently to preclude a satisfactory bone-grafting operation or other type of osteosynthesis, the Brackett operation is applicable. Henderson feels that this procedure is surgically sound, being most suitable for the younger patients with nonunions.

Technic—The hip is exposed by an anterior iliofemoral incision, its distal limb being curved posteriorly (p 149) or by a lateral incision through the interval between the tensor fascia femoris and the gluteus medius muscles (p 150) The capsule of the joint is incised in line with the neck of the femur and all of the dense scar tissue is excised from the region of the nonunion. The fractured surface of the head of the femur is freshened and excavated to form a concavity or socket for the distal fragment. After this process, the cancellous surface of the proximal fragment should present a fresh, bleeding surface. The remnants or stump of the neck of the femur are removed flush with the shaft from the distal fragment. The greater trochanter is now resected and the freshened surface of the *top of the shaft, i e.,* the former site of the greater trochanter is fitted into the previously prepared concavity in the head fragment. (Ghormley and Rowe point out that one of the most difficult yet most crucial steps in this operative procedure is the proper *mobilization* of the upper part of the femoral shaft that good mobility must be secured before the lower fragment is brought into *apposition* with the upper fragment) The head should fit in a more or less upright or valgus position, and should be fixed by

some form of metallic fixation (Fig 474) Finally the trochanter with its attached muscles, is anchored to the shaft one to two inches below its original site

After Treatment.—A spica cast is applied from the toes on the affected side and the knee on the opposite side The cast is bivalved at the end of five or six weeks, to allow active and passive motion. Usually at the end of eight weeks postoperatively the patient is able to walk with crutches. Subsequent treatment depends upon the progress of the union

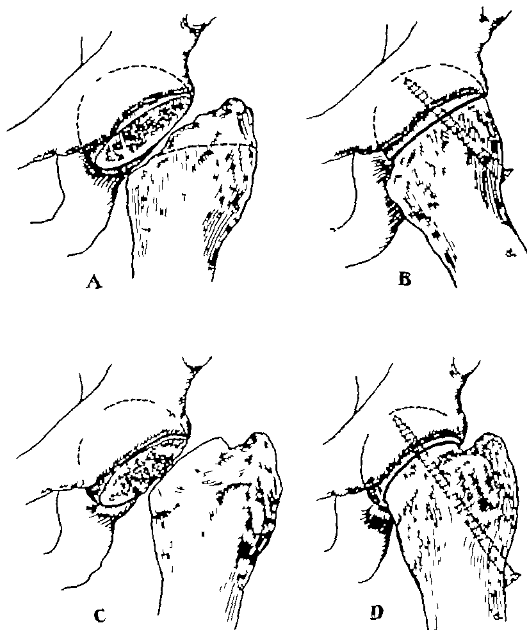


Fig. 474.—Brackett operation. *A* and *B* If neck is completely absorbed, trochanter is denuded to raw bon and placed in excavated head fixation secured by large Vitallium screw Gluteal muscles transplanted distally on shaft. *C* and *D* If neck is well preserved, fracture surfaces are freshened and neck placed in concavity of head of femur

Technic (Luck)—The hip joint and anterior surface of the intertrochanteric region are exposed by an anterior iliofemoral incision After incision of the capsule throughout its length the fractured surface of the head

is freshened A transverse osteotomy is then carried out near the lower border of the remainder of the femoral neck, thus, the greater trochanter and a portion of the base of the neck lie above the osteotomy The remaining portion of the femoral neck is resected, leaving the trochanter with the attached abductor muscles undisturbed The femoral shaft is then placed directly *beneath and approximated* to the adducted head The trochanter is placed against a denuded area on the shaft distally and maintained in position by means of a Steinmann pin, which passes upward and inward through the trochanter, shaft, and head

After Treatment.—A double spica cast is applied incorporating the pin Both external and internal fixation are removed at eight weeks and weight bearing is gradually instituted

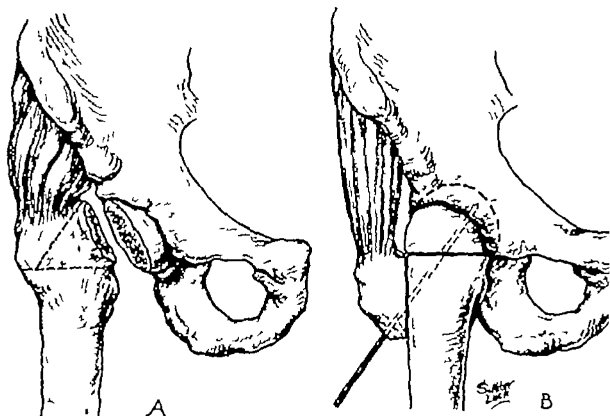


Fig. 474.—Luck reconstruction operation. *A*, Wedge-shaped section of bone removed, as indicated by dotted lines. *B* Shaft displaced directly beneath head of femur Trochanter attached at lower level. Relationships maintained by Steinmann pin. (Redrawn from Luck, J V J Iowa M. Soc. 28: 620 1938.)

RECONSTRUCTION OPERATION

Restoration of normal anatomy is impossible following necrosis *or absorption* of the fragments and one cannot, therefore, *hope to reestablish* normal function In the majority of cases however by well selected reconstruction operations, *one* can assure the patient a stable weight bearing extremity, with material *improvement in* function Bony support is provided by the insertion of the *proximal* end of the *distal* fragment into the acetabulum

In the presence of a nonviable head, if the neck is relatively well preserved, the Whitman or Albee *reconstruction* procedures are preferable. The Colonna operation is utilized if the neck has been absorbed.

The common causes of failure following reconstruction are displacement of the neck or trochanter from the acetabulum, gluteal weakness and a hip limp arthritic changes, and shortening Function is usually less satisfactory than following the average osteosynthesis or osteotomy

Smith Petersen and his co-workers have used Vitallium-mold arthroplasty in 42 patients that presented various complications following fractures of the neck of the femur Depending upon the extent of the degenerative changes, four general types of mold arthroplasties were used.

Routine Mold Arthroplasty—This procedure is utilized when union of the central fracture of the neck of the femur has occurred and the aseptic necrosis of the head of the femur is limited, or minimal. The depressed portion or necrotic area is excised to bleeding bone, and the larger defects obliterated by cancellous bone from the ilium Aside from this variation, the technic is similar to the technic described in Chapter XVII

Modified Whitman Reconstruction Operation.—A Whitman reconstruction procedure is combined with mold arthroplasty if the head of the femur is necrotic. If the neck is relatively long transplantation of the greater trochanter may not be necessary if the neck is short, or if absorption subsequently takes place, the mold may come to rest on the trochanter thereby producing pressure changes accompanied by pain. Or a short neck may rotate out of the mold, thus, transplantation of the trochanter to a lower level is necessary producing a relative lengthening of the neck of the femur and providing the abductor muscles a more efficient leverage

If union takes place but necrosis of the major portion of the head develops, the entire head is resected, the neck reshaped and the combined procedure, described above, is carried out.

Modified Colonna Reconstruction Operation.—The Colonna procedure is combined with mold arthroplasty in the presence of a nonunion of the neck of the femur an viable head and more or less complete absorption of the neck. Because of the tendency of the greater trochanter to subluxate when the hip is adducted, Smith Petersen deepens the acetabulum by one-half inch or so This is accomplished by a shelf osteotomizing the anterior inferior ilium in a vertical plane and springing the outer cortex laterally Bone grafts from the iliac crest are then wedged into the crest to maintain the lateral position of the outer cortex. To prevent impingement on the anterior lip of the cotyloid notch the lesser trochanter is exposed subperiosteally and excised, leaving the distal expansion of the iliopsoas muscle intact.

Intertrochanteric Mold Arthroplasty—Smith Petersen and his co-workers report two instances wherein the greater trochanter could not be utilized for a modified Colonna. In one instance after excision of the lesser trochanter the intertrochanteric region was reconstructed to fit the mold the greater trochanter being transplanted to the infratrochanteric region of the shaft. In another instance due to previous extravagant use of internal fixation, the screw had performed a partial osteotomy of the greater trochanter subsequently it was a simple matter to greenstick the greater trochanter medially and downward and counteract the tendency toward subluxation, which the normal lateral deviation of the trochanter encourages. After osteotomy the greater trochanter was fixed to the shaft by a three-flange nail

Whitman Reconstruction Operation

Technic —The incision is begun one inch posterior to the anterior superior spine and curved distally and posteriorly to cross the femur three inches below the tip of the trochanter The approach employed for the bone peg operation is also applicable Dissection is carried down between the tensor fasciae femoris and gluteus medius muscles, the capsule is incised, and the head of the femur is delivered At the point of insertion of the gluteus medius muscle, the base of the trochanter is divided obliquely to correspond to the angle of the neck the muscular attachments to the trochanter remaining undisturbed This flap of muscle and bone is turned upward and backward The upper extremity of the femur is next denuded of soft tissues, remodeled, and reduced into the acetabulum at an angle of 135 degrees' abduction, with moderate internal rotation The trochanter is then brought down as far as its muscular attachments will permit and approximated to the lateral aspect of the femur, at this point the shaft of the femur is scarified The raw surface of the trochanteric fragment is apposed to this area and so maintained by a screw, nail, or sutures placed through drill holes in the fragment and shaft

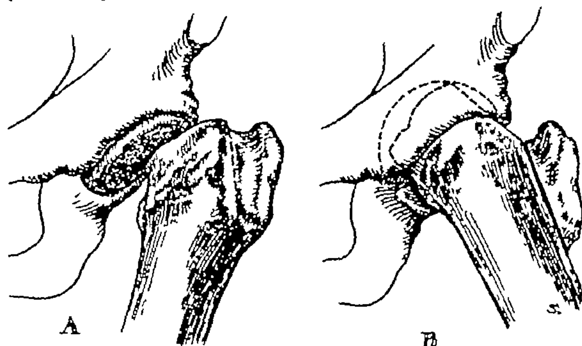


Fig. 478 —Whitman reconstruction operation. *A* Line of division of trochanter with attachment of abductor muscles. *B* Head removed, neck reduced into acetabulum abductor muscles attached at lower level on femur (Redrawn from Whitman, Royal Surg. Gynec. Obst. 50: 886 1930.)

This procedure establishes the necessary leverage for action of the abductor muscles in balancing the pelvis and prevents adduction and possible dislocation of the upper extremity of the femur from the acetabulum.

After Treatment.—Immobilization is maintained by a double spica cast with the hip in 135 degrees abduction and moderate internal rotation. The cast is bivalved at the end of four weeks and roentgenograms are made to determine the relation of the newly constructed articulation At this time, cultivation of motion in both hip and the knee is begun by means of an overhead pulley under control of the patient. Between exercise periods, rest in the back half of the bivalved cast is enforced for an additional two weeks,

especial care being taken to keep the hip in abduction and moderate internal rotation until a fair degree of muscle power returns. At the end of eight weeks, weight-bearing is resumed with the aid of crutches. Unsupported weight bearing should not be attempted before the lapse of four to six months.

Colonna Reconstruction

The reconstruction procedure devised by Colonna is particularly applicable to ununited fractures of the neck of the femur wherein absorption of the neck is practically complete and the head is not viable



Fig. 477—Whitman reconstruction operation in patient aged forty nine years. Excellent function.

Technic.— A curved incision is made, beginning about one inch behind the anterosuperior spine and curving downward and crossing the femur about five inches below the tip of the greater trochanter The fascia is divided and all the muscles attached to the greater trochanter are carefully cut near their insertions, care being taken *not to remove any portion of the underlying bone* but to leave the upper extremity of the femur covered by a thin layer of muscle and fibrous tissue.

The capsule is then opened longitudinally after which it is divided transversely close to the greater trochanter in order to preserve as much of

the capsule as possible. The limb is then rotated outward and adducted, the upper extremity of the femur is freed by sectioning the pyriformis, gemelli, and obturators close to their insertions The loose head is then removed and the cervico-trochanteric region is inspected If spicules of the fragment of the neck remain, they are chiseled off flush with the inner surface of the shaft and this raw area is covered over with adjacent tissue.

After the greater trochanter has been completely freed of all its muscle attachments, it can be easily pulled down and placed deeply within the acetabulum In all of the patients operated on the greater trochanter has been found easy of reduction and of a size which has permitted it to be sunk deeply within the acetabulum The thickened capsule and abductor muscles are then pulled down holding the limb in about 20 degrees of abduction

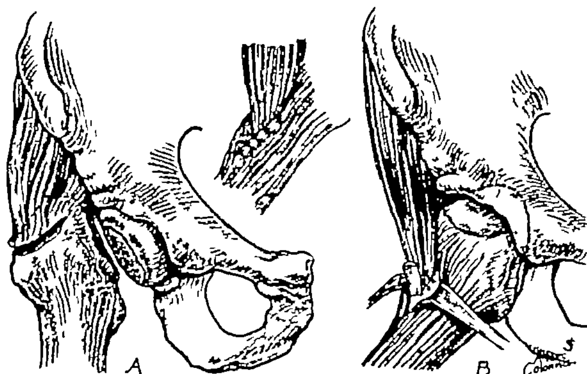


Fig. 478.—Colonna reconstruction operation. *A* Abductor muscles detached, leaving a soft tissue covering over trochanter *B* Trochanter reduced into acetabulum, abductor muscles attached to shaft of femur (Redrawn from Colonna, Paul J Bone & Joint Surg 17 110, 1935.)

The fibers of the vastus lateralis are then identified and separated subperiosteally, exposing the shaft of the femur A bony trough is made on the lateral aspect as far down as the abductor muscles will reach when the limb is in about 20 degrees of abduction. Before preparing the bony flap in the shaft of the femur, care is taken to have the patella pointing upward. Two small drill holes are then made in the shaft in the anteroposterior plane, the muscles are drawn down snugly to this position and held in place by kangaroo tendon, and the bony flap is sutured over the mass. The vastus lateralis is then carefully reefed over the new insertion of the gluteus medius and gluteus minimus.'

After Treatment.—See above

The foregoing operation is claimed to be advantageous in that the investiture of living fibrous tissue is conducive to a greater range of motion,

and there is practically no loss in length of the extremity The method has been criticized on the ground that the trochanter may subluxate after the extremity is brought down parallel to the opposite one This, however has not been our experience in the small number of cases wherein the technic was followed.

Albee Reconstruction

To prevent dislocation of the hip following reconstruction operations Albee created a lever whereby the action of the abductor muscles is facilitated. As the extremity is adducted the outward excursion of the proximal end of the lever places tension on the trochanteric muscles and surrounding soft parts, thus holding the proximal end of the femur within the acetabulum.

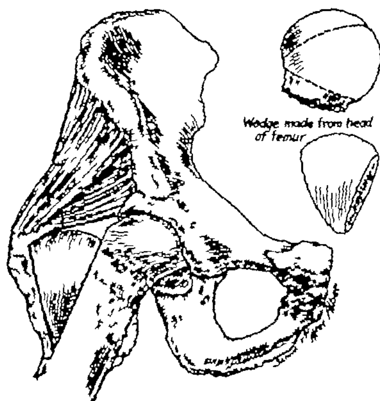


Fig. 479.—Albee reconstruction operation. L-shaped lever with insertion of abductor muscles maintained in lateral position by wedge of bone from head of femur Neck reduced into acetabulum. (Redrawn from Albee, Fred H. Injuries and Diseases of the Hip New York, 1937 Paul B. Hoeber Inc.)

Technic.—The fracture site is approached through an anterior iliofemoral incision The muscles on the wing of the ilium are stripped subperiosteally and retracted, the capsule is entered by a T-shaped incision and the head of the femur removed and preserved. With the leg rotated internally, the soft parts are severed down to the anterior surface of the trochanter in the form of an inverted L. Into the clefts thus created a one and one-half inch osteotome is placed in line with the long arm of the L, and another one-half inch in width, is placed along the short arm The osteotomes are driven through the trochanter simultaneously separating the inverted L-shaped lever intact the broader osteotome is driven from above downward, the circumflex artery being avoided. This fragment which should be four inches in length, is pried

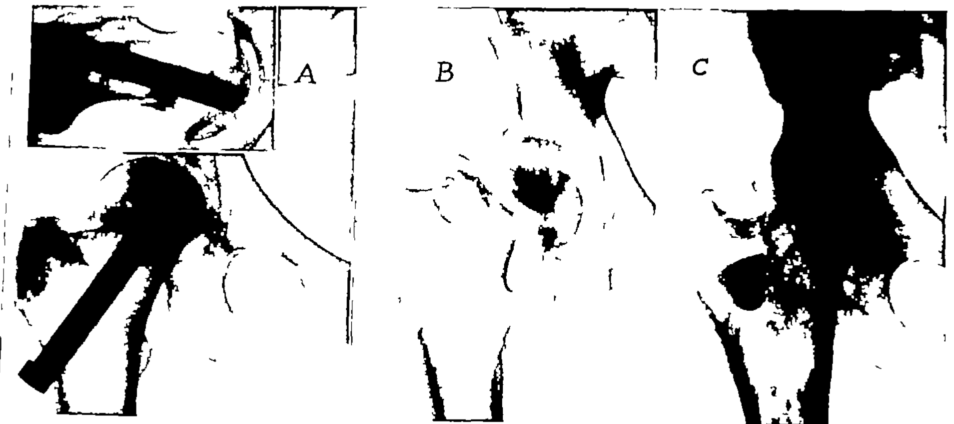


Fig. 480.—*A* Fracture of neck of femur adequately nailed. *B* At eleven months, nonunion with aviable head. *C* Treated by Albee reconstruction procedure. Note wedge-shaped segment of head in split trochanter

laterally, creating a greenstick fracture at its distal end. The insertion of the abductor muscles is undisturbed at the proximal end of the bone-muscle lever To preserve the length of the extremity, the short arm of the L should include as little of the trochanter as possible The stump of the femoral neck is then remodeled and reduced into the acetabulum as the extremity is brought to the limit of abduction The gap formed by prizing the bone lever outward is filled by a wedge shaped section of bone from the excised femoral head. The upper end of the bone lever is held in position by medium kangaroo tendon sutures through the surrounding soft tissues.

After Treatment —*See above*

Trochanteric Arthroplasty

Philip Wilson has employed an operation, which he calls trochanteric arthroplasty, wherein the trochanteric end of the shaft of the femur is reshaped, covered with a Vitallium cup and placed in the acetabulum. The instruments for a mold arthroplasty are necessary to the proper execution of this procedure.

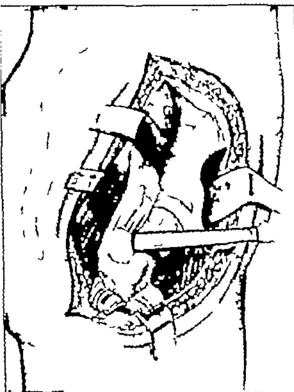




Fig 481 —P D. Wilson trochanteric arthroplasty *A* Hip exposed through Callahan approach. Trochanter being removed together with attachments of gluteal muscles. *B* Head of femur being removed. (From Wilson, P D. J Bone & Joint Surg. 29: 313 1947)

Technic (Wilson) —The hip joint is exposed by a modified Smith Petersen incision, the distal end of the incision curving posteriorly over the lateral surface of the thigh. To expose the trochanteric end of the femur the tensor fasciae femoris is divided transversely in line with the skin incision the upper portion of the femoral shaft is then exposed by subperiosteal dissection through the vastus lateralis muscle In a sagittal plane the greater trochanter is osteotomized, the insertions of the gluteal muscle being undisturbed. In order to pre

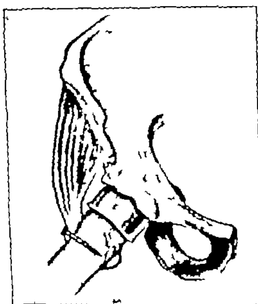


A

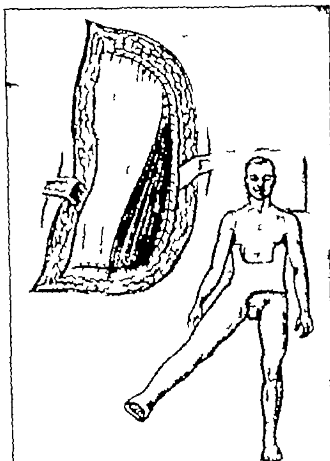


B

Fig. 482.—Same as Fig. 481 *A*, Trochanter being shaped to fit Vitallium cup. *B* Acetabulum reshaped with reamer (From Wilson, P D. J Bone & Joint Surg. 29: 313 1947)



A



B

Fig. 483.—Same as Fig 481. *A*, Trochanter reduced into Vitallium cup. Gluteal muscles reattached at lower level on shaft. *B* Closure of wound and postoperative fixation by a cast, with hip in abduction. (From Wilson, P D.: J Bone & Joint Surg. 29: 313 1947)

serve a relatively substantial trochanter a minimal amount of bone should be removed. After division of the capsule the distal fragment is rotated laterally exposing the head fragments The scar tissue is excised, the head of the femur is removed and the acetabulum reshaped The shaft of the femur is then grasped with Lane forceps and pulled out of the wound to allow division of the short external rotator muscles After this procedure, the distal fragment is completely mobilized, and the trochanteric end is remodeled and rounded so as to fit properly into a Vitallium cup While the extremity is held in abduction, the trochanteric fragment is then reduced into the acetabulum. The stability of the joint is checked both with and without the cup in place A tendency toward luxation on adduction may be due to impingement of the shaft against the inferior and medial border of the acetabulum, the use of a Vitallium cup which is too large or to shallowness of the acetabulum. All ligamentous remnants which may have become interposed between the femoral shaft and the inferior border of the acetabulum are trimmed away including if necessary a part of the bony margin. The acetabulum if too small may be enlarged or deepened. Thereafter with the cup in the acetabulum, the trochanteric fragment is reduced into the cup and the extremity maintained in approximately 135 degrees abduction The gluteal muscles together with the trochanteric fragments are reattached to the femur as far distally as possible and fixed with a Stuck nail

After Treatment.—The hip is immobilized in a position of slight extension and 135 degrees abduction by means of a plaster cast. The cast is maintained for a period of four to six weeks, though a portion may be removed earlier to permit motion of the knee joint. Exercises and physical therapy are then begun. Usually weight-bearing is not permitted until eight to ten weeks following operation.

OSTEOTOMY

Two general types of osteotomies are employed for ununited fractures of the neck of the femur the high osteotomy (McMurray) and the low osteotomy (Schanz) The first is carried out just above the level of the lesser tubercle, and the other just below the lesser tubercle or lower if required because of the amount of shortening

The mechanical advantages of either method of osteotomy are as follows (1) the line of weight bearing of the extremity is shifted directly beneath the head of the femur and the hip joint (2) the shearing force at the fracture site is decreased by reduction of the angle of inclination between the surfaces of the head and neck, i e the fracture line is more horizontal than vertical (3) the normal leverage of the trochanter is reestablished

It should be recognized that osteotomy involves a mechanical principle which may be embodied in a rather wide variety of technics. These operative procedures are also applicable to a rather wide group of ununited fractures. An osteotomy enthusiast may extend the limits of the indications for osteotomy from the initial fresh fracture to the ultimate in nonunions. We have never utilized this procedure for any fresh fracture, however nor in our opinion, is it suitable for old ununited fractures with absorption of the neck, excessive shortening of the extremity and a semiviable head.



Fig. 484.—*A*, Ununited fracture of neck of femur treated by McMurray osteotomy. *B*, excellent functional result one year postoperatively. *C*, Nine years postoperatively there are beginning arthritic changes. Range of motion in hip joint has decreased proportionately.

Briefly (1) when the structures are well preserved, as in relatively recent nonunions, metallic osteosynthesis with or without a graft is utilized in preference to an osteotomy (2) When the indications as described for the Brackett operation (p 659) are present, osteotomy in lieu of this procedure is a matter of individual preference and experience We prefer the osteotomy The mechanical end result of the two methods is essentially the same, though accomplished by a different technic In young individuals, the more complicated and exacting osteotomy-synthesis (Dickson) may be employed. In elderly or debilitated patients, the simpler safer technics are indicated this feature represents in our opinion, one of the important advantages of osteotomies. (3) If the head is viable, reconstruction operations are preferable. In some cases, after osteotomy union may take place despite an viable head, though the ravages of time and wear produce an arthritic joint with a gradual decrease in function over a period of two to five years (4) If the head is small and atrophic, though viable, the neck absorbed, and an established pseudarthrosis with laxity (p 655) is present, the prospect of union after osteotomy is less favorable. Although the patient may have sufficient support to permit improved function, the hip is unstable unless union takes place between all three fragments With a continuation of the nonunion, despite the improved mechanics, endurance is likely to be poor and the hip eventually becomes painful This result, in a poor surgical risk, is preferable to noninterference In a better risk, a reconstruction operation would be preferable.

A detailed analysis of the end results of a substantial series of osteotomies is not available. Our general impression of 74 osteotomies is as follows the results are more or less proportionate to the mechanical and physiologic status of the nonunion prior to osteotomy if the head is viable, and union takes place, function approaches normal. Following osteotomy obviously the more abnormal the bony structures, the more unfavorable the outcome. A disappointing percentage of excellent or good results at one year must be graded downward two to five years postoperatively because of aseptic necrosis and progressive arthritic changes

Most of our experience has been limited to the high osteotomy when union takes place between all three fragments an ideal anatomic and mechanical status reflects as an excellent functional hip With questionable viability of the head, the extra stability afforded by a low osteotomy if union does not occur is desirable and is a better mechanical status than nonunion following a high osteotomy

High Osteotomy

In a high osteotomy bony support may be restored either by the induction of osseous union or by so changing the line of weight bearing that, even though nonunion persists weight will be borne in a direct line with the head of the femur The procedure is particularly suitable for elderly and debilitated individuals who cannot withstand extensive reconstruction operations definite improvement of an otherwise hopeless disability is thus possible

According to McMurray s original technic, the femur was divided, the distal fragment placed directly beneath the head and the hip immobilized by a cast. In this procedure, however the distal fragment may be displaced for-

ward by the iliopsoas muscle Further, the lateral angulation of the trochanter may be lost The disadvantages of a cast are obvious. To circumvent these undesirable features yet simplify the surgery as much as possible two operations have evolved (1) if the neck is well preserved and the hip reducible osteosynthesis of the fracture is obtained by two Knowles pins, and the osteotomy is fixed by a reversed Blount or Neufeld nail (2) if the neck is short the osteosynthesis is omitted, only the osteotomy being fixed By this rather flexible fixation of the osteotomy site (original with Neufeld), a process of readjustment and settling is allowed, which assures contact of the shaft fragment with the trochanteric and neck fragments

The McMurray osteotomy should not be too oblique to the longitudinal axis of the femur nor should it include any part of the base of the neck a medial projection of bone will interfere with complete displacement of the shaft beneath the head.

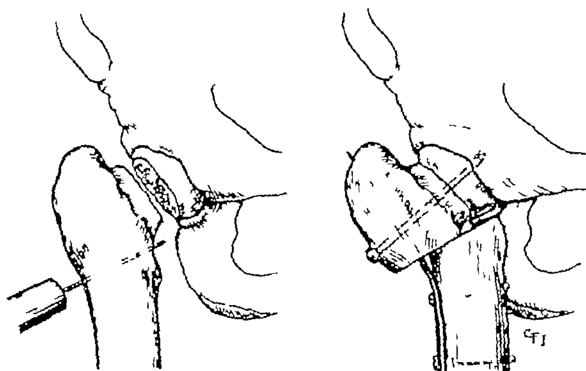


Fig. 485.—Modification of McMurray *osteotomy* *A* Guide pin inserted along line of contemplated division of bone Prior to *osteotomy* position checked by roentgenograms. *B* After division of bone, shaft of femur displaced under head, and fixed to trochanter by a reversed blade plate or Neufeld nail. If neck is short, Knowles pins are omitted.

The operation is performed with the patient on the fracture table in a manner similar to that used for fresh fractures of the neck of the femur (Fig 80) Prior to the incision two-view roentgenograms are made of the hip to determine the relationship of the head to the neck.

Technic—Beginning at the greater trochanter, an incision six inches in length is made in line with the shaft of the femur (p 179) The vastus lateralis muscle is incised in the line of incision stripped from the anterior surface of the femur in the region of the contemplated osteotomy and maintained in the medial position by means of a Blount anvil retractor Two guide pins are then inserted the first along the line of the contemplated osteotomy, beginning on the lateral surface of the femur level with the lesser trochanter,

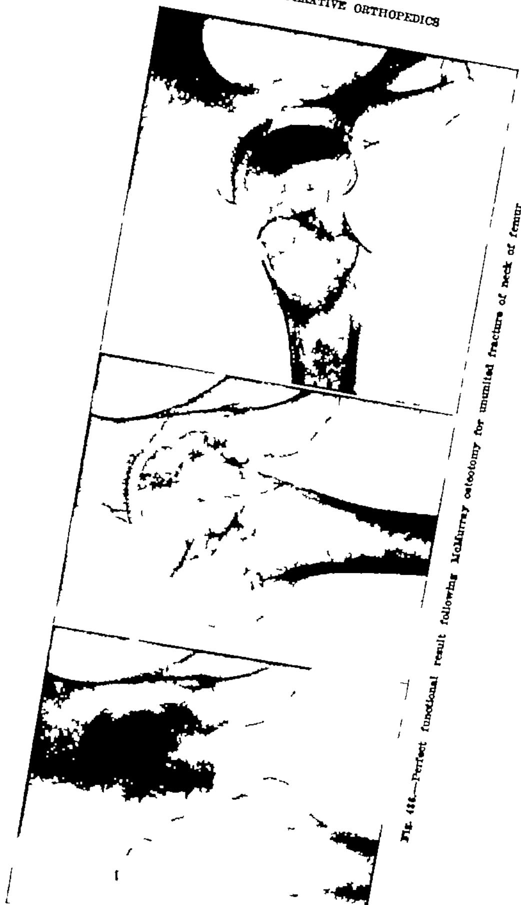


Fig. 436.—Perfect functional result following McMurray osteotomy for ununited fracture of neck of femur

and extending obliquely upward and inward to emerge on the medial surface of the femur just above the lesser trochanter The second guide pin is inserted slightly proximal to the first, through the trochanter neck and into the head The latter guide pin is used as a landmark for the proper insertion of Knowles pins. (This last feature is omitted if the neck of the femur is short, and osteosynthesis is not advisable.) Roentgenograms are next made in both planes to verify the position of the two guide pins. Two Knowles pins are then inserted through the trochanter, into the neck and head, at points sufficiently wide apart



Fig. 487 Aseptic necrosis of head of femur following high McMurray osteotomy is an undesirable sequelae. *A* Ununited fracture of neck of femur with head apparently viable. *B* Excellent functional result with solid union of all three components of osteotomy at one year *C* Two years postoperatively, there is beginning aseptic necrosis. *D* Three years post operatively patient is incapacitated. *E* After arthrodesis.

to permit the insertion of a blade plate between the pins. The femur is cleanly divided with an osteotome Thereafter the distal fragment is abducted while pressure is exerted on the proximal portion of the lower fragment until the shaft is displaced inward beneath the head of the femur The accurate placement of the distal fragment is verified by visualization palpation and by roentgenograms.

The osteotomy is fixed by a blade plate (Neufeld or Blount), which is bent at an angle of 150 degrees (Fig 485) The short end of the blade is inserted into the intraosseous portion of the trochanter, and brought through the top of the trochanter In an osteoporotic bone, this is accomplished with only slight pressure. With the shaft abducted, the blade is fixed to the shaft by means of three screws. After completion of this procedure, the shaft should be well displaced beneath the head, and the trochanter should be at an angle of not less than 150 degrees with the shaft. Final checkup roentgenograms verify this position.

After Treatment.—No immobilization is used postoperatively Quadriceps setting exercises are begun as soon as they can be tolerated, and are supplemented by resistive exercises at approximately two weeks postoperatively The patient is encouraged to sit up in bed, and to move around within the limits of the pain At eight weeks, the patient is allowed up on crutches, but with only minimal weight bearing The progress of union determines the subsequent course of treatment. As a rule, unrestricted activities are permissible at six months

Low Osteotomy—Schanz

The Schanz femoral osteotomy at the lower level was designed to create contact between the lateral aspect of the pelvis and the femur at the osteotomy site and thus to re-establish a partial bony support and change the line of

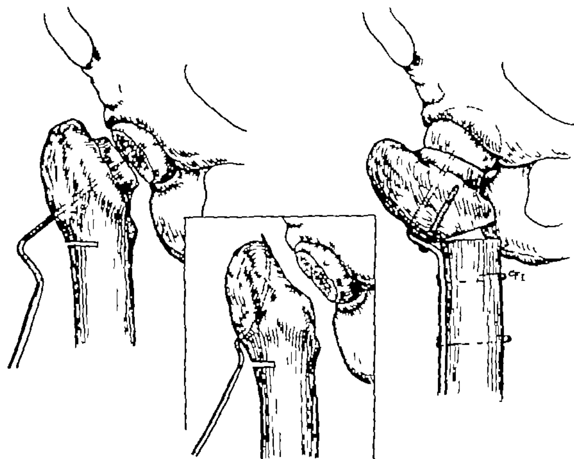


Fig 486.—Blount osteotomy *A* Osteotomy of femur partially completed prior to insertion of blade. With gooseneck of nail snugly seated against trochanter long screw is inserted through bol in gooseneck. After osteotomy is completed, blade portion of nail is transfixed to shaft by screws. Insert shows technic of fixation when neck is entirely absorbed.

weight bearing to a more mesial plane This technic was applied to ununited fractures *after excision of a degenerated head, congenital dislocation* of the hip and other deformities, it is still applicable, provided better skeletal support cannot be obtained by other means.

According to the present concept, the Schanz osteotomy at the lower level is not intended to provide a partial pelvic support for a continuous nonunion or loss of support above, rather, the shift in the line of weight bearing and the change in the line of inclination at the fracture site is designed to induce union

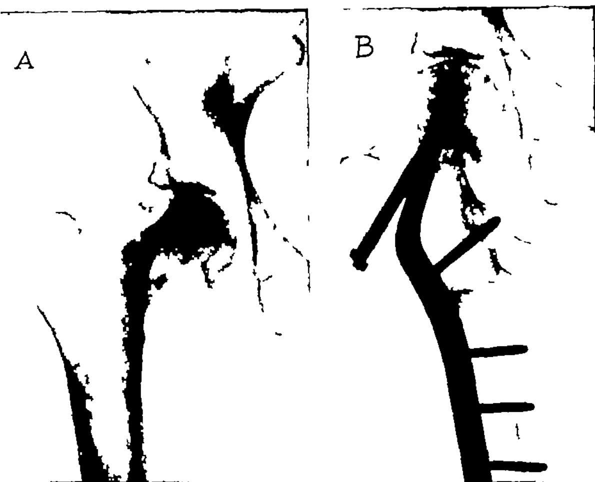


Fig. 489 —*A* Ununited fracture of neck of femur treated by Blount osteotomy *B* Fixation of head and neck reinforced by two Knowles pins. Six months after operation, patient had solid union and a good functional result.

The Schanz femoral osteotomy although based on surgically sound principles, was not popular for many years because of the difficulty in controlling the fragments. Malposition or even nonunion was a distinct possibility Blount has eliminated this undesirable feature by developing an effective means of internal fixation, the double-angle blade plate Fixation is sufficiently firm to maintain position and obviate the necessity for external fixation.

Blount feels that an osteotomy at the level of the lesser trochanter, as described below is preferable to the McMurray osteotomy, in that a more satisfactory degree of angulation of the trochanter is possible, thereby re-establishing the function of the abductor muscles.

The operation should be carefully planned. The preoperative roentgenograms should be placed on the view box and the outline of the hip traced on

brown paper With scissors and paste, the operation may be outlined and the proper angulation of the osteotomy usually about 40 degrees, may be determined.

While a large variety of sizes of the gooseneck blade plate should be available at the operating table, one should closely estimate the proper length of the trochanteric neck head segment of the nail before operation. The length of this nail varies somewhat according to the changes in the bone incident to the ununited fracture. The proximal end of the blade should engage



Fig. 499—Solid union of ununited fracture of neck of femur functional result marred by beginning aseptic necrosis of head.

the head of the femur only if a relatively satisfactory reduction is possible, the head fragment is viable, and the neck is fairly well preserved. If the fracture is comparatively recent, fixation of the head neck fragment is best accomplished by multiple pins, prior to insertion of the blade

If the neck fragment has undergone rather marked *absorption*, a *short* blade which does not impale the head permits readjustment in a stable position, precludes the possibility of protrusion of the blade through the head into the acetabulum, and still provides quite satisfactory fixation.

If the neck has been entirely absorbed, the blade may be reversed and inserted through the trochanteric fragment, thence down the shaft, as illustrated in the insert in Fig 488 Blount points out that the screw inserted through the gooseneck into the proximal fragment is an important stabilizing feature

Technic (Blount)—The lateral aspect of the trochanteric region and the upper portion of the shaft of the femur are exposed by a lateral incision (p 179) The use of an anvil retractor, inserted subperiosteally from the front to the medial aspect of the femur, will assist in maintaining exposure with a minimum of effort One-half inch below the prominence of the greater tubercle a guide pin is introduced in line with the neck of the femur A drill is next inserted transverse to the longitudinal axis of the femur at the level of the proposed osteotomy site, i e lower edge of the lessor trochanter, this point is ordinarily about ¾ inch distal to the guide pin Roentgenograms are then made in both views to verify position of the guide pin and the osteotomy site The position having been verified, the lateral one third of the osteotomy of the femur is completed before insertion of the blade plate The known length of the guide pin in the trochanter neck fragment further establishes the desired length of the proximal end of the blade plate With the aid of a driver, the gooseneck nail is inserted into the trochanter and neck at the desired angle, a simple protractor aids immeasurably in the accuracy of this portion of the operation Any discrepancy in the angle may be corrected by the use of small bending irons. With the gooseneck portion of the nail snugly seated against the trochanter, a long screw is inserted through the hole in the gooseneck and thence into the trochanter engaging if possible, the opposite cortex. Thereafter, the osteotomy is completed by means of a Gigli saw or by a drill and a thin osteotome, with care to avoid comminution of the bone The distal fragment is then abducted until the shaft is flush with the distal portion of the blade The procedure is completed by fixation of the blade to the shaft with screws of proper length. The final position of the blade and osteotomy are verified by roentgenograms

After Treatment.—External fixation is unnecessary As a rule the patient may be allowed up on crutches at the end of eight weeks, the amount of weight bearing being determined by the progress of the union

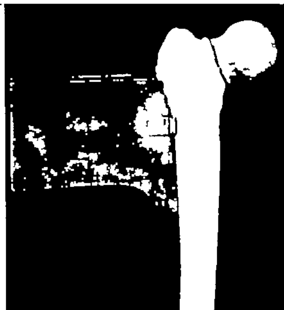
OSTEOTOMY OSTEOSYNTHESIS

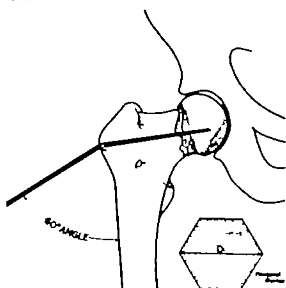
James A. Dickson has devised a technic that combines high osteotomy with osteosynthesis The osteotomy is quite unique in that the femur is divided in such a way as to change the angle of weight-bearing by an exact 60 degrees If nonunion is recognized early before sclerosis and absorption occur the high geometric osteotomy is employed alone. In the later cases, this procedure is combined with osteosynthesis Dickson feels that the use of the graft not only facilitates union but may prevent further impaction at the fracture site

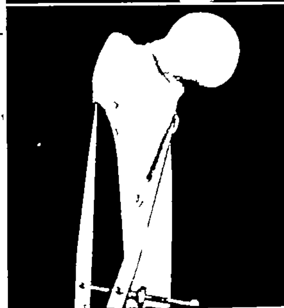
Dickson emphasizes that procedures for nonunions should be carried out early before unnecessary complicating factors occur that with impending nonunion, as evidenced by absorption slipping or change in angulation at the fracture site, these cases inevitably go from bad to worse Operations for nonunion undertaken at an early date are likely to eventuate in a higher percentage of good functional results than if operative procedures are delayed.

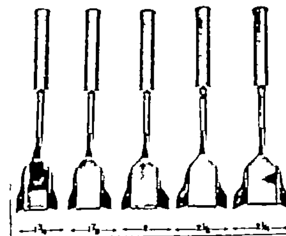
If internal fixation has been removed, traction may be applied for a few days prior to operation thereby, bringing the stump of the neck of the femur











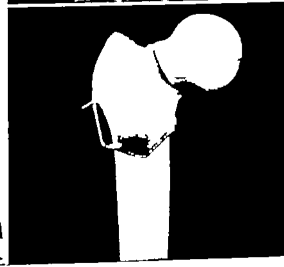


Fig. 491.—J. A. Dickson osteotomy-osteosynthesis. *A*, Roentgenograms showing placement of guide wire. *B*, Special protracto *C*, Placement of Jewett nail. *D*, Method of measuring for proper diameter of semihexagonal chisel. *E*, Semihexagonal chisels. *F*, Preliminary placement of chisel, to insure the correct diameter

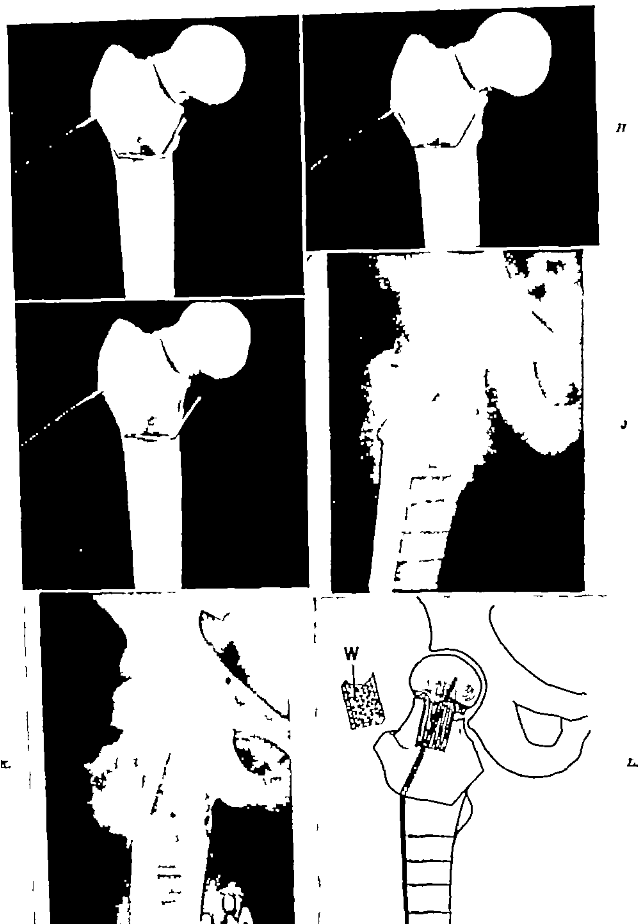


Fig. 491 (*Cont'd*) —*G*, Placement of chisel to mark osteotomy site. *H* Effect of a chisel of too small diameter *I* Effect of a chisel of too large diameter *J* Postoperative roentgenograms of *A*. *K* Roentgenogram of another case eighteen months after osteotomy-osteosynthesis. *L* Removal of window *W* for excision of fibrous tissue and placement of bone grafts. (From Dickson, J A.: J Bone & Joint Surg. 29: 1005 1947)

opposite the head of the bone. Ordinarily, if internal fixation has remained intact, the fragments are in a sufficiently satisfactory position for the procedure, even though considerable varus deformity exists from absorption of the head and neck fragments.

Preliminary to the operation the patient is arranged on the fracture table so that roentgenograms may be made of the hip in both planes Preliminary roentgenograms are made to establish that the proper degree of traction, abduction, and rotation have secured the optimum position.

Technic (Dickson, J A.) —*The hip joint, trochanter and lateral aspect of* the femur are exposed by the Callahan approach (p 149), or the Watson-Jones approach (p 150) carrying the incision distally so as to expose the upper six *or seven inches of the shaft. The vastus lateralis is reflected medially After* removal of any previously inserted internal fixation a guide pin is passed from a point just a little above the prominence of the greater trochanter into the *lower half of the head of the femur This is accomplished with the aid of a* special protractor which assures accurate placement of the pin at right angles to the longitudinal axis of the femur (Fig 491 *A* and *B*) Roentgenograms are made to verify the position of the pin and the length of the blade that will be necessary ordinarily 2¼ to 2¾ inches. A proper sized Jewett nail with an angle of 150 degrees is threaded over the wire, driven into place, and the fracture surfaces are impacted. At this stage, the Jewett nail extends from the shaft at 60 degrees (if there has been little absorption of the neck, and the head is riding high in relation to the prominence of the trochanter it may be advisable to insert the guide wire at 75 degrees to the longitudinal axis of the femur and use a Jewett nail with an angle of 165 degrees)

The lesser trochanter is now palpated the distance from the point where the blade plate enters the prominence of the greater trochanter to the upper surface of the lesser trochanter is calculated with a caliper (Fig 491*D*) A semihexagonal chisel, with a diameter of this width is chosen from the set of five chisels. The diameter of these chisels vary in width by one-eighth of an inch from one and three-fourths inches to two and one-fourth inches (Fig 491*E*) The proper chisel is then used to mark the site of the osteotomy With a proper sized chisel placed vertically on the front of the femur with the diameter extending from the entrance of the blade plate to the lesser trochanter one side of the marker extends beyond the flare of the trochanter (Fig 491*F*) If the chisel is now rotated slightly so that one side runs parallel to the flare of the trochanter extending distally from the entrance of the blade plate, the site of the osteotomy can be marked along the other two blades. This brings the inner blade out just above the lesser trochanter thus assuring a high osteotomy (Fig 491*G*) If the chisel is too small, the osteotomy will extend into the neck (Fig 491*H*) and much of the support of the head segment will be lost. If too large the osteotomy will come out below the lesser trochanter (Fig 491*I*), and the impacting force of the psoas will not be procured. The measurements determining the choice of the proper marking chisel is extremely important, in order to obtain optimum results from the osteotomy

The osteotomy is completed with a thin osteotome. A little traction is applied at this stage and the osteotomy site is thoroughly mobilized. The distal fragment is then lifted anteriorly so that the proximal segment can rotate freely

beneath it Further traction is applied and the leg brought out into slight abduction The two segments are then angulated slightly forward and reapposed in the new position Traction can then be released and the plate fixed to the shaft of the femur (Fig 491J)

When the osteotomy and rotation have been completed, a window is created in the neck just distal to the fracture site This readily allows removal of sclerotic bone and fibrous tissue from the fracture site through this window the adjacent portion of the head of the femur is curetted, creating a cavity for reception of the grafts (Fig 491K) Numerous chips of cancellous bone from the ilium are impacted well across the fracture line and one large graft is then fixed into position to give added stability The window is then replaced

After Treatment.—Internal rotation is maintained in balanced traction, or with a plaster boot and bar On the first postoperative day, the prothrombin time is checked and 300 mg of Dicumarol are given. The prothrombin time of the blood is followed and supplementary doses of Dicumarol given as needed, to keep the prothrombin level from 30 to 50 per cent of normal and this check is continued for a ten-day period

Six to eight weeks postoperatively the patient is allowed up with crutches. Roentgenograms are made as progress studies from time to time and protection is continued until there is evidence that the head is thoroughly revascularized and the fracture united.

ARTHRODESIS

Gill observes that the primary advantage of arthrodesis for ununited fracture of the neck of the femur lies in the freedom from pain a stable weight bearing structure, and a relatively useful and functional extremity He denies that this procedure should be utilized as a last resort that if one is fairly certain that a satisfactorily functioning extremity, which includes mobility, cannot be properly consummated arthrodesis should be performed primarily

Gill lists the following contraindications to osteosynthesis rapid or excessive absorption of the neck of the femur aseptic necrosis of the head of the femur or arthritic changes in the hip joint

He feels that the conditions which contraindicate arthroplasty or reconstruction procedures are marked absorption of the neck of the femur, arthritic changes in the hip joint, or a rigid and painful lumbar spine

He is of the opinion that necrosis of the head of the femur degenerative arthritis, complete absorption of the neck of the femur with marked upward displacement or rigid and painful backs, are definite contraindications to osteotomy

Arthrodesis, we believe, is rarely indicated for ununited fractures of the neck of the femur If some degree of function cannot be restored by the procedures listed above, the patient, ordinarily had best be left alone. In our experience, fusion under these circumstances is extremely difficult to accomplish.

Technic (Gill)—Through an Ollier incision the joint is exposed and final conclusions are drawn as to the relative merits of arthrodesis vs operations which will permit mobility Assuming that the former is indicated the capsular and tendinous attachments are severed subperiosteally to a point one inch below the greater trochanter The head of the femur is removed from

the acetabulum, and the latter is denuded of its articular cartilage and enlarged upward into a dome shape The raw denuded end of the trochanter is then placed into the acetabulum. In some cases, the intra-articular arthrodesis may be reinforced by a graft from the greater trochanter This is driven into a cleft in the acetabulum so as to contact the femur

After Treatment.—Fixation in a plaster cast is maintained for at least twelve weeks.

UNUNITED FRACTURES OF THE MANDIBLE

Occasionally nonunion of the mandible follows either clean or infected fractures, necessitating surgical repair The execution of the procedure is relatively simple but success may be doubtful if the area about the fracture site is surrounded by a preponderance of avascular scar tissue or if a dormant infection is relighted

For the larger defects of the mandible, viz., those of more than three centimeters in length, curved, free iliac or rib grafts must be utilized to fill the defect. The graft is instituted in much the same manner as for defects elsewhere. For nonunion with minimal defects, the technic described below is adequate.

Sliding Graft

The following operation is advantageous in that an additional incision for removal of a graft is not required. Further, the soft tissue attachments to the graft are preserved so far as possible, thus maintaining its blood supply No originality is claimed for this procedure.

Technic.—An incision is made along the lower border of the mandible and the soft structures are stripped sufficiently to expose the ends of the fragments. The soft tissue attachments to the inferior margin of the body of the mandible are maintained intact. The fractured surfaces are denuded of scar tissue and freshened Fixation is maintained by a wire loop passed through drill holes in the outer table of each fragment adjacent to the fracture site. With a motor saw, the inferior border of the body of the mandible is removed, one inch being taken from the shorter fragment and two inches from the longer The shorter segment is preserved in a sterile towel. The two inch segment with the soft tissues intact is transplanted so as to bridge the fracture site inferiorly and held in place by one Vitallium screw inserted vertically through the graft into the body of the mandible Cancellous bone from the ilium may be utilized to fill any defects between the ends of the bone. A cigarette drain should be left in place for twenty four hours.

After Treatment.—A dental splint is inserted to hold the mandible in proper position until postoperative nausea has ceased. The teeth are then wired together as for a fresh fracture of the mandible Immobilization is continued for four weeks.

Inlay Graft

Technic (Albee).—After proper exposure the fractured surfaces of the mandible are denuded of scar tissue and freshened. A bed is next prepared for the graft by removal of a rectangular section from the outer cortex of each

fragment A straight or slightly curved tibial graft of appropriate size is then mortised into the bed and held in place by chromic catgut sutures (In the light of present knowledge a rib graft or curved iliac graft would be preferable)

After Treatment.—See above

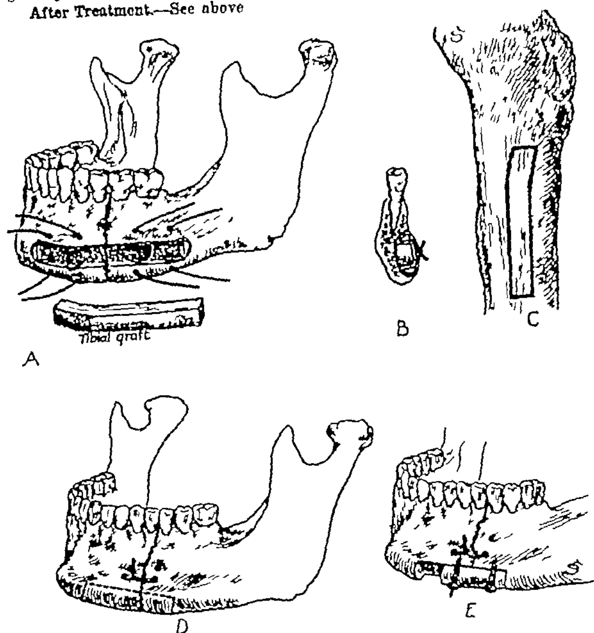


Fig. 492.—Nonunion of mandible. *A*, *B*, and *C* Inlay graft (technic, Albee) *D* and *E* Massive sliding graft. Soft tissues left attached to preserve circulation to transplant.

UNUNITED FRACTURES OF THE CLAVICLE

Nonunion of fractures of the clavicle usually result from considerable loss of continuity of the bone, particularly following compound or comminuted fractures. Only fractures of the medial three fourths of the clavicle require bone grafting those of the outer two inches being treated by resection of the lateral fragment, as described for dislocations of the acromioclavicular joint (p 349) If the ends of the fragments can be apposed, a single onlay bone graft supplemented by cancellous bone is adequate

For bridging defects in the clavicle Basom and associates suggest dual onlay grafts one on the superior surface and one on the inferior surface The

defect is adequately bridged by tibial grafts one-half inch wide and four to five inches long A trough is provided for cancellous fragments and fixation is adequate This procedure may also be used if the fragments of the clavicle are excessively osteoporotic, even though the ends may be opposed the forceps-like action of the onlay grafts provides a firm grip and stable fixation. The technic of the dual onlay bone graft of the clavicle is essentially the same as that employed in the long bones (p 625)

Technic.—An incision six inches in length is made just below the clavicle. The periosteum is incised and stripped from the anterior half of the bone and a small portion of the cortex is freshened with a chisel A curved graft from the tibia four to six inches in length and three fourths inch in width, is prepared as an onlay graft and applied to the denuded upper or under surface. Fixation is secured by four metallic screws. Cancellous bone from the tibia or ilium is packed in and around the fracture site.

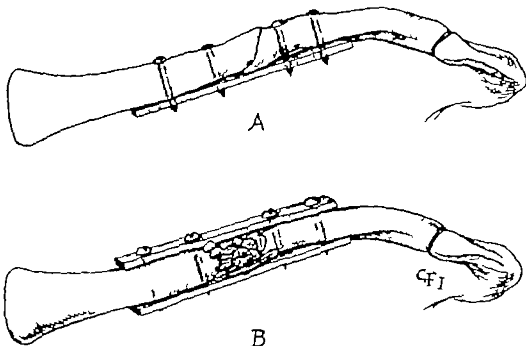


Fig. 493 —A Onlay bone graft for ununited fracture of clavicle. B Dual onlay bone graft for bridging defect, or for fixation of osteoporotic fragments.

After Treatment.—A Velpeau dressing is applied. The patient is then kept on a Bradford frame for a period of six weeks, a small pad being inserted between the shoulders to produce slight hyperextension of the shoulder girdle At the end of six weeks, the dressing is removed and active and passive motion are begun in the shoulder and elbow, the extremity however is carried in a sling for one month thereafter

UNUNITED FRACTURES OF THE HUMERUS

Ununited Fractures of the Upper Third of the Humerus

For ununited fractures of the surgical neck of the humerus, a combined intraosseous and intramedullary graft is employed

Technic.—The head and upper three inches of the shaft of the humerus are approached through a Henry or anterior incision (p 181) The fragments

are freshened and placed in satisfactory alignment With a three-eighths inch drill, a hole is made from above downward adjacent to the greater tubercle into the medullary cavity of the lower fragment A graft from the tibia slightly larger than the drill, is passed through this hole and into the medulla of the lower fragment a distance of three inches. The fragments are then closely approximated

After Treatment—The shoulder is immobilized on an abduction humerus splint for four to six weeks. Thereafter hanger exercises and physical therapy are begun, and activity is increased and protection decreased proportionate to the progress of union

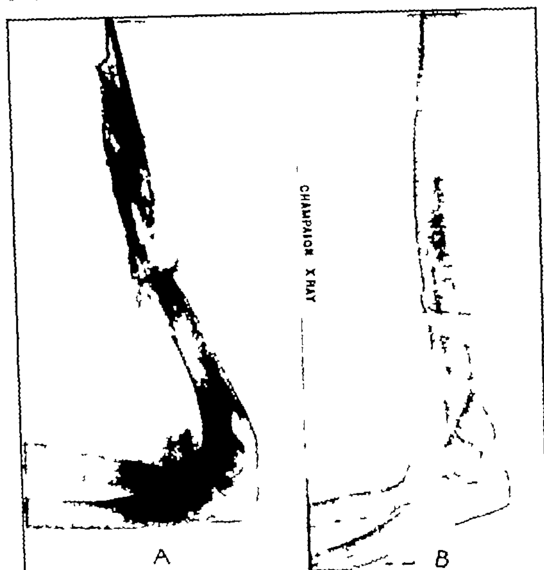


Fig 494.—*A* Unsuccessful onlay graft with beef bone screws applied elsewhere. *B* Solid union two years after onlay graft.

Ununited fractures just below the surgical neck of the humerus are best treated by a combined onlay and intraosseous graft.

Technic—The upper extremity of the humerus is exposed by the Henry or anterior, approach (p 181) and the fractured ends are freshened and apposed. A flat surface is created on both fragments the major portion being on the lower because of the contour of the head Above the flat surface of the

upper fragment a tunnel one-half inch in diameter and two inches in length is made into the head on a plane with the shaft A massive graft with a pointed end is prepared as for an onlay graft. The pointed end is then driven through the tunnel in the head and the remainder is fixed to the flat area on the proximal and distal fragments by screws. Cancellous bone from the tibia is packed about the fracture site

After Treatment.—See above

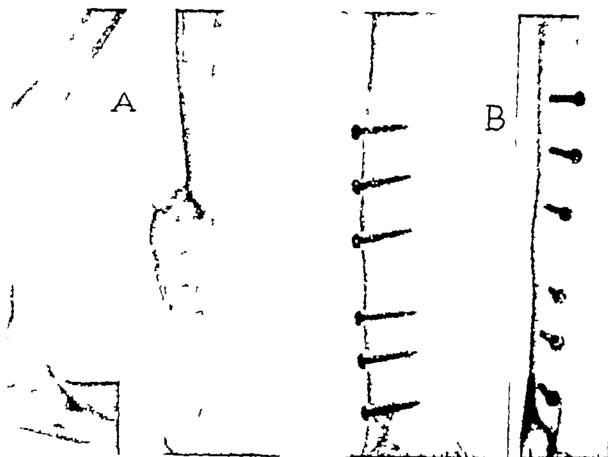


Fig. 491.—A single onlay bone graft provides adequate fixation for shaft of humerus. Typical pseudarthrosis, middle and lower third of shaft. B Ten months postoperatively ...aft is thoroughly reorganized and amalgamated with host fragment.

Ununited Fractures of the Shaft of the Humerus

Nonunion of fractures in this region is observed in a fairly large number ... cases. Union has been obtained in 93 per cent of our cases by the ...e of the onlay graft regardless of the duration of the nonunion and the ...thologic and physiologic status of the fragments. In the humerus, it is less ...ten necessary to bridge a defect than in the other long bones. Preferably the ...agments should be apposed and grafted even at the expense of one and one-...alf to two inches shortening Shortening of one and one half inches is associated with little or no disability the cosmetic effect being the only consideration ...d this is of no consequence in comparison with the bridging of a bone defect ...he technic of the operation is described on p 619 Aside from fractures in ...e region of the condyles and metaphyseal portion of the lower end of the ...merus, the Henry approach (p 181) provides an excellent exposure

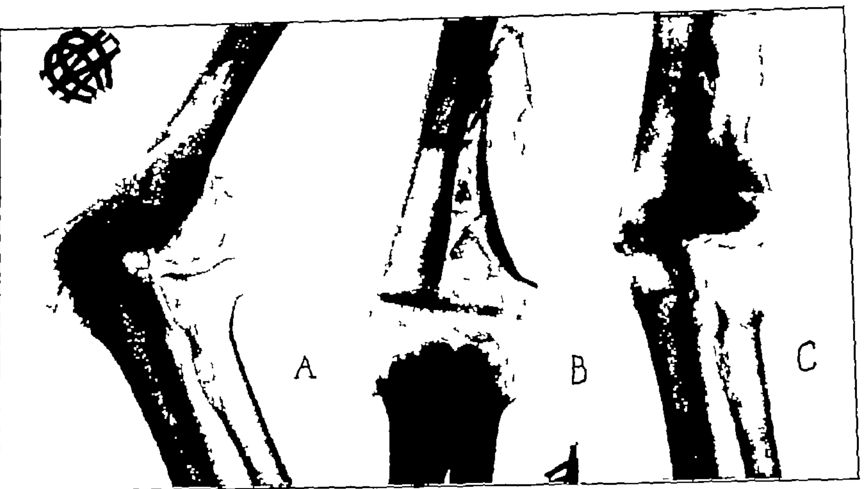


Fig 406—*A* Old fracture of external condyle of humerus in childhood; marked cubitus valgus, and nonunion. *B* Immediately after reconstruction operation. *C* Twelve months postoperatively normal range of flexion and extension restored, with normal carrying angle, fifty per cent supination and pronation, and fair stability

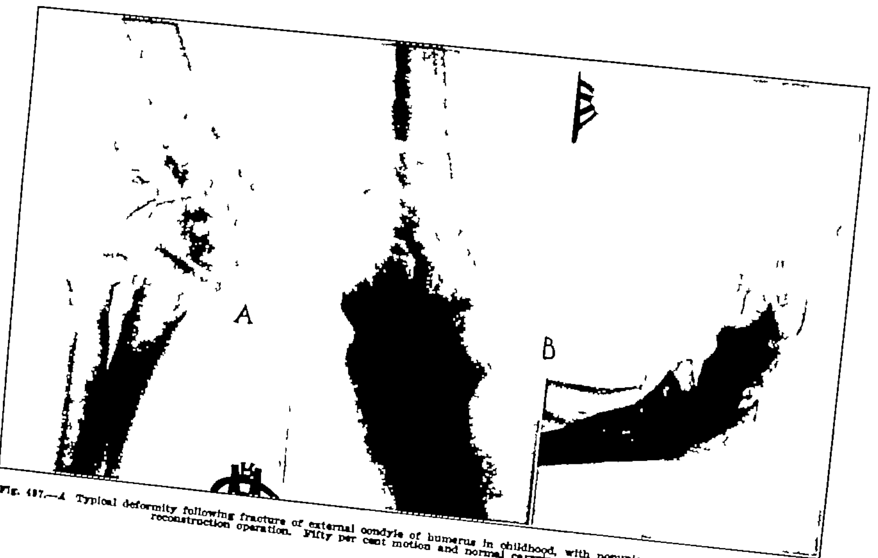


Fig. 497.—*A*, Typical deformity following fracture of external condyle of humerus in childhood, with nonunion. *B*, Thirteen months after reconstruction operation. Fifty per cent motion and normal carrying angle. No pain.

Ununited Fractures of the Condyles of the Humerus

Nonunion of the internal epicondyle of the humerus may be observed following inefficient treatment (p 486) of the fresh fracture Even though the epiphyseal surfaces are widely separated however, and fibrous union joins the loose fragment to the internal condyle, function is practically normal unless there is an associated ulnar neuritis. No attempt is made to secure bony union between the epicondyle and the humerus neurolysis and transposition of the ulnar nerve anteriorly (p 773) is usually sufficient treatment. The bony fragment may be excised from the common origin of the flexor muscles.

Disability from nonunion is practically limited to fractures of the external condyles in children If the fragments are not perfectly apposed and immobilized when fresh union usually not only fails to take place but is accompanied by an extreme cubitus valgus deformity and undue laxity of the elbow from abnormal growth An asymptomatic joint had best be left alone Transplantation of the ulnar nerve anteriorly provides in most instances, adequate relief from an ulnar nerve palsy If the joint is painful and unstable, surgical interference is justifiable The following procedure is applicable to adults stability and strength may be restored but the range of motion is ordinarily decreased

Technic.—The incision is begun over the lateral aspect of the lower third of the humerus and extended downward a distance of four inches, to end just below the elbow joint above the head of the radius. By subperiosteal dissection, the anterior and posterior aspects of the fracture site are exposed and the surrounding adhesions and soft tissues are dissected free only the muscular attachments to the external epicondyle being conserved This fragment is quite large and must be remodeled Both fractured surfaces are freshened, closely approximated and held together by two screws of appropriate length and size. The space above the restored external condyle is filled in with bone shavings and grafts from the ilium

For a persistent ulnar neuritis, the nerve is transferred forward on the anteromedial aspect of the forearm through a separate incision (p 773)

After Treatment.—The elbow is immobilized in a posterior elbow splint. Passive and active exercises and physical therapy are begun at the end of six weeks.

UNUNITED FRACTURES OF THE UPPER THIRD OF THE ULNA WITH DISLOCATION OF THE HEAD OF THE RADIUS (MONTEGGIA FRACTURE)

Ununited fractures of the upper third of the ulna are often associated with dislocation of the head of the radius No attempt is made to reduce the head of the radius instead, one inch of the proximal portion is resected (p 494) An onlay graft is applied to the lateral surface of the ulna (p 619)

UNUNITED FRACTURES OF ONE OR BOTH BONES OF THE FOREARM

In the presence of a nonunion of both bones of the forearm the problem is usually relatively simple Resection of the fragment ends well within the permissible amount of shortening (one and one half inches) usually equalizes

the length of the bones and at the same time eradicates viable bone. Single or dual onlay grafts have produced union in over 90 per cent of our cases. The approaches to these bones are described in Chapter IV To minimize the increase of the cubic contents of the forearm and thereby facilitate closure the grafts are usually only slightly thicker and wider than an ordinary metallic

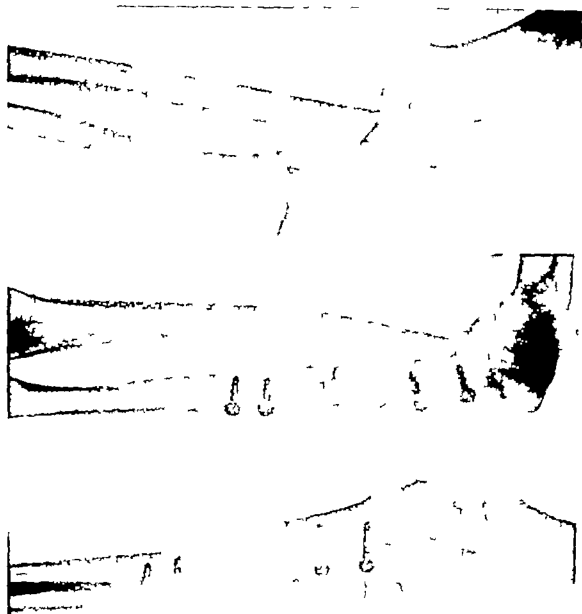


Fig 491.—A Ununited Monteggia fracture of twelve years' duration. Patient previously had an open reduction and resection of head radius elsewhere. B Six months after onlay bone graft and resection of proximal end of radius range of motion in elbow 40 170 degrees.

plate Care must be exercised to restore the bones to their exact anatomic relations, not only as to alignment and apposition but as to rotation otherwise, pronation, or supination will be materially limited The same untoward result, together with pain at the distal radio-ulnar joint will follow if there is a material disproportion in length of the two bones

The grafting of both bones of the forearm at one operation constitutes a major surgical procedure and should not be undertaken without previous experience in grafting in other less difficult areas. If two surgical teams are available, the procedure may often be carried out within the limits of tourniquet time.

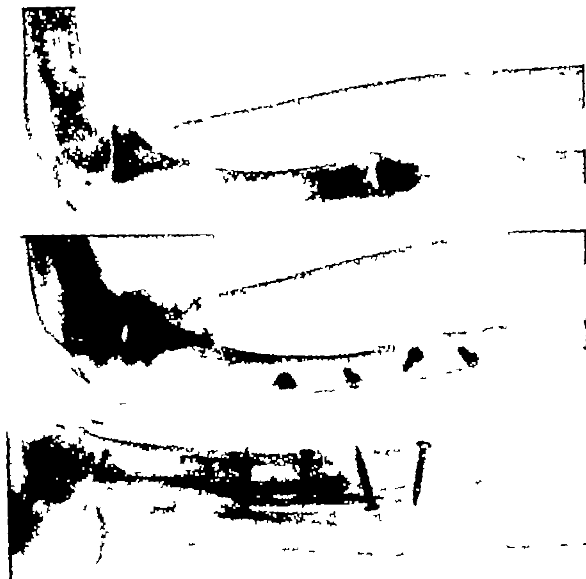


Fig. 499.—Patient observed nine weeks after conservative treatment elsewhere. Head of radius partially luxated, but apparent beginning union of ulna. Orbicular ligament reconstructed. *A*, Roentgenogram eight months after injury showing incomplete union. *B*, Rather than resect head of radius, sclerotic area and defect in ulna bridged by dual onlay bone graft. Note groove in neck of radius cut by tight reconstructed orbicular ligament. Motion in elbow from complete flexion to 165 degrees, supination 75 per cent, pronation normal. Patient resumed occupation as structural steel worker.

Sliding grafts or inlay grafts are not satisfactory for the radius or the ulna, for the following reasons: (1) the small caliber of these bones makes the operation technically difficult; (2) resection of at least one-third of the circumference of the bone is necessary for a graft of adequate size. This unnecessarily weakens or damages the shaft adjacent to the fracture site and, if the original procedure fails, interferes with the execution of subsequent operations.

If one of the bones of the forearm fails to unite without shortening of the other, grafting is difficult unless the opposite bone is shortened. Usually this is

permissible only if the intact bone is united in a severe degree of malposition precluding function. In the latter event, sufficient bone is resected from the malunited area to produce equality in length Onlay bone grafts are then applied to both bones to insure union. The use of a metallic plate for the mal united fracture subjects this bone to the possibility of a nonunion.

When shortening of the normal bone is undesirable and a defect exists in the ununited bone the residual space cannot be closed because of splinting of the normal bone. It is preferable to span this defect with a fibular graft, rather than shorten the normal bone and risk the possibility of a nonunion (p 705)

The bridging of the shorter defects may be satisfactorily accomplished with a little less technical detail by the dual onlay graft (p 625) the intervening trough being filled with cancellous bone from the ilium As Boyd has previously pointed out, single onlay bone grafts are not advisable for defects, regardless of the length, because of the tendency to the formation of an hourglass constriction at the defect, subsequent refracture through this area is likely

Variations in or combinations of the two fundamental methods, onlay grafts, or technics for bridging defects, may be adapted to unusual types of forearm fractures For example, short defects in one bone may be filled with a portion resected from an overlap of the other and thereafter reinforced by a single onlay graft (p. 619)

If a flare-up of an old infection in one bone is anticipated, a two-stage operation may be advisable The uninfected bone is operated upon first. After union is complete in this fracture, the more hazardous procedure may be undertaken on the second bone without fear of jeopardizing the result in the first. This plan is also advantageous in that the trauma is reduced to a minimum

Ununited Fractures of Proximal End of Ulna

Ununited fractures of the olecranon, i.e, those fractures proximal to the trochlea, present little difficulty A strong fibrous union may be only slightly disabling In middle-aged or elderly individuals, surgical intervention may *not be justified In others, treatment consists of excision of the ununited frag* ment and reattachment of the distal fibrous expansion of the triceps tendon to the ulna The technic is similar to that described for fresh fractures (p 492)

The difficult member of this group is the comminuted fracture which extends well distal to the trochlear process, with anterior dislocation of the distal fragment of the ulna and the head of the radius into the anterior compartment of the elbow joint. Frequently these are the result of side-swipe fractures, and are associated with other disabling injuries. Many have been compound infected and, in general neglected. The following technic is not warranted unless the injury is more or less isolated. In the presence of an associated malunion from gross comminution of the condyles of the humerus, a modified arthroplasty, or resection (Chs. XVII and XIV) may be preferable

Technic—Under a turniquet with the arm across the chest the posterior aspect of the elbow joint is exposed by a Boyd incision (p 187) If necessary the medial aspect of the posterior capsule may be split to allow further retraction of the olecranon process. Thereafter the head of the radius and the proximal end of the distal fragment must be mobilized sufficiently to permit correction of the anteriorly displaced position. This phase of the procedure may be long

tedious, and difficult. The radius is osteotomized through the neck, and the head resected. This provides considerably more working space and facilitates subperiosteal dissection of the coronoid process. All dissections should be subperiosteal on both sides of the ulnar shaft, proceeding cautiously with regard for the important structures which pass across the front of the elbow joint. Dissection must continue until the ulna can be restored to its proper position and realigned with the olecranon process. Even though this defect is slight, no attempt should be made to approximate the olecranon process to the shaft of the ulna. This







Fig. 500.—*A* Ununited fracture of olecranon, with forward displacement of head of radius and distal fragment of ulna. The inadequacy of a wire loop for fixation of this fracture is obvious. Intramedullary fixation, or an obliquely placed transfixion screw would have been preferable. *B* and *C* After dual onlay bone graft.

will result only in a pinching of the condyles of the humerus. In fact, the fit of the olecranon and coronoid to the trochlea and the olecranon fossa should be rather loose. The defect in the ulna is bridged by a dual onlay graft, the trough being filled with iliac bone.

After Treatment.—The elbow is immobilized at a right angle and the forearm in midposition by means of a plaster cast from the axilla to the palm. The cast is bivalved to allow for swelling. Immobilization is continued for a mini

mum period of six to eight weeks. Ordinarily, grafts in this region 'take' rather rapidly. Thereafter routine exercises and physical therapy are carried out.

A reconstruction of the elbow joint along these lines cannot be expected to produce a normal elbow joint. In many cases, motion will be materially restricted. The anatomy is restored, however, to provide a satisfactory foundation for a subsequent arthroplasty.

Ununited Fractures of the Distal End of the Ulna

Ununited fractures of the distal two or three inches of the ulna are best treated by a Darrach's resection (p. 597). Fractures proximal to this area should be treated by a routine onlay bone-graft procedure.

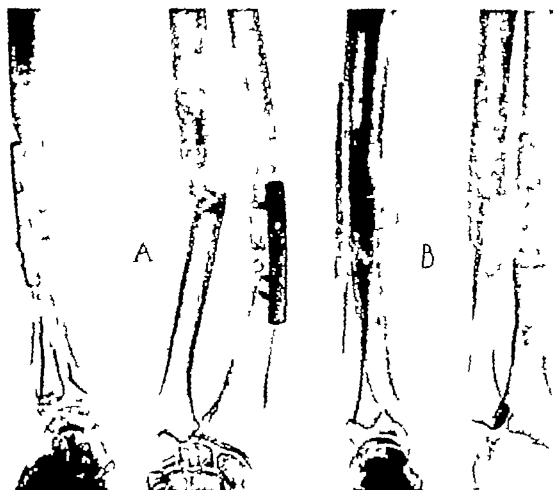


Fig. 561.—A, Nonunion of fracture of both bones of forearm. Vitallium plate are [illegible] where. B. Three months after onlay bone graft.

UNUNITED COLLES' FRACTURE

(See Malunited Colles' Fractures, see Difficult and Unusual

UNUNITED FRACTURES OF THE CARPAL SCAPHO

There is a marked similarity both anatomically and patholog tween fractures of the carpal scaphoid and central fractures of th the femur. The blood supply to the proximal fragment is severely by fracture and in neglected cases, a permanent status of nonunio

reached Although to the uninitiated a fracture of this bone appears to be a minor ailment inefficient treatment leads rapidly to a serious disability of the wrist

A perusal of the results of treatment of ununited fractures of the scaphoid bone during World War II impresses one with the importance of prophylaxis. Almost unanimously, it is reported that from 85 to 90 per cent of fractures of the scaphoid bones, if recognized early and properly treated, will unite within four to five months We agree with Soto-Hall and Murray that if union has not taken place within this period further immobilization is definitely unjustified Even though union may be possible (and in our experience it is by no means certain) the side effects of immobilization over a long period of time are likely to be more than the aftermath of properly indicated and properly executed surgery Other than arthrodesis, the success of surgery is predicated on intervention prior to the development of arthritic changes.

During World War II the results of treatment of ununited fractures of the scaphoid bones in military services were unsatisfactory Here again, the results must be interpreted in the light of such factors as improper indications, inadequate surgery and psychic disturbances. From a review of these results, however, considerable negative information is obtained which, interpreted inversely, may be incorporated into the indications for the various surgical procedures described below

Soto-Hall who with Haldeman manifested a great deal of interest in this lesion prior to the war and added to his experience during World War II, has provided us with some rather definite indications for various procedures, and some rather definite ideas as to what can be expected in the way of function With only a few minor changes, we subscribe to Soto-Hall s tenets and acknowledge our indebtedness to him for much of the information below

The following surgical procedures have, in the past, been applied to nonunion of the fractures of the scaphoid bone

1 The drilling operation.

2 Excision of one or both fragments of the scaphoid bone, excision of the proximal row of carpal bones

3 Bone graft operation.

4 Arthrodesis of the wrist.

Before undertaking any of the above procedures, the advisability of withholding treatment should be considered As stated by Clarke some wrists do very well with nine bones instead of eight ' We have followed such a policy in middle aged or elderly individuals with nonunion of long standing who engaged in sedentary occupations Some of these patients were not exactly sure when the fracture occurred and symptoms had become particularly troublesome only after recent trauma. In the decision between interference and noninterference one should be governed by his own experience with the surgical treatment of nonunion of the scaphoid bone

Drilling Operation

Drilling of the scaphoid bone may be dismissed quickly the high percentage of failures of union following this relatively simple procedure is sufficient to condemn it in favor of more definitive operations

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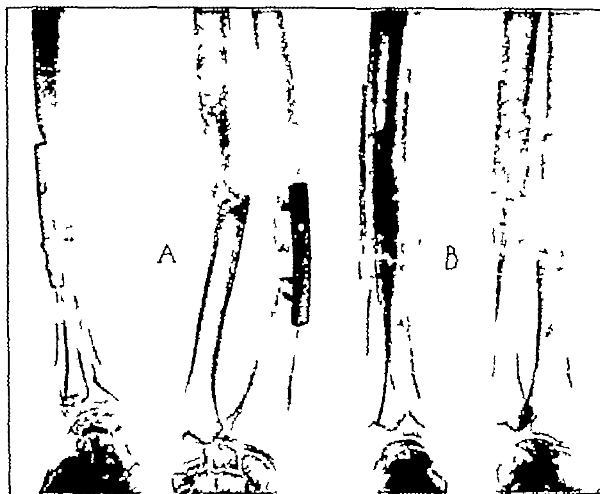


Fig. 561.—A, Nonunion of fracture of both bones of forearm. Vitallium plate applied elsewhere. B, Three months after onlay bone graft.

UNUNITED COLLES FRACTURE

(See Malunited Colles Fractures, see Difficult and Unusual Nonunions.)

UNUNITED FRACTURES OF THE CARPAL SCAPHOID

There is a marked similarity both anatomically and pathologically between fractures of the carpal scaphoid and central fractures of the neck of the femur. The blood supply to the proximal fragment is severely impaired by fracture and, in neglected cases, a permanent status of nonunion is soon

reached Although to the uninitiated a fracture of this bone appears to be a minor ailment inefficient treatment leads rapidly to a serious disability of the wrist

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The following surgical procedures have, in the past, been applied to nonunion of the fractures of the scaphoid bone

1 The drilling operation

2 Excision of one or both fragments of the scaphoid bone excision of the proximal row of carpal bones

3 Bone-graft operation.

4 Arthrodesis of the wrist.

Before undertaking any of the above procedures, the advisability of withholding treatment should be considered As stated by Clarke some wrists do very well with nine bones instead of eight We have followed such a policy in middle aged or elderly individuals with nonunion of long standing who engaged in sedentary occupations Some of these patients were not exactly sure when the fracture occurred and symptoms had become particularly troublesome only after recent trauma In the decision between interference and noninterference one should be governed by his own experience with the surgical treatment of nonunion of the scaphoid bone

Drilling Operation

Drilling of the scaphoid bone may be dismissed quickly the high percentage of failures of union following this relatively simple procedure is sufficient to condemn it in favor of more definitive operations.

Excision of One or Both Fragments

Excision of Proximal Row of Carpal Bones

Two of these three possibilities should be eliminated from the armamentarium of surgical treatment of nonunion of the scaphoid bone. Excision of both the radial and ulnar fragment of the scaphoid may produce an immediately satisfactory result. Soto-Hall, however, reports that in their cases and in others they have observed, the os magnum protrudes into the space which was occupied by the scaphoid bone. Five to seven years may elapse before the shifting of the distal carpal row allows sufficient protrusion to cause symptoms and deformity. It seems unquestionable that the loss of the entire scaphoid bone is likely to produce a mechanical derangement of the wrist, and should be abandoned in favor of arthrodesis. Much the same objections may be raised to excision of the entire proximal row of carpal bones. This is an excessively radical procedure which is likely to result in an unstable and painful wrist, with a far less desirable result than an arthrodesis.

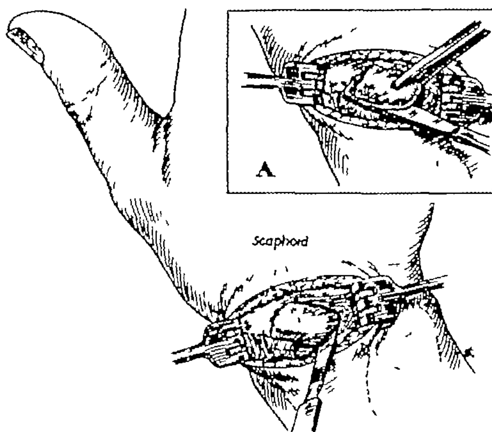


Fig. 601.—Excision of scaphoid. One or both fragments may be removed.

In our experience the result of excision of the ulnar fragment of the scaphoid bone, when indicated, is likely to be satisfactory. The loss of a relatively *small fragment*, i.e., *one-fifth to one-seventh of the bone, impairs motion* in the wrist less than any of the operative procedures. Further postoperative immobilization is minimal and return of function is fairly rapid. Most of these patients report some loss of strength in the wrist, though actual disability in the wrist may be difficult to ascertain on clinical examination.

The indications for excision of the ulnar fragment of the scaphoid bone are as follows

(1) When the ulnar fragment consists of one-fifth to one-seventh of the carpal scaphoid bone, regardless of its viability, attempts at bone grafting of such small fragments are likely to fail

(2) When the ulnar fragment consists of one third or less of the size of the scaphoid bone and the fragment is necrotic or comminuted

(3) When bone grafting procedures have failed, though the status of the fragments is still within the specifications listed in (1) and (2)

(4) The indication for excision is questionable if the viable ulnar fragment represents more than one-third of the scaphoid bone When a major portion of the scaphoid is excised, the result may be expected to approach those of total extirpation of the bone

(5) Even in relatively fresh fractures, excessive comminution of the fragments may be an indication for early excision, as a precaution against late arthritic changes in the wrist

Technic.—The skin and deep fascia on the radial aspect of the dorsum of the wrist are incised transversely for two inches, the incision is level with the styloid process of the radius. The abductor muscles of the thumb are retracted anteriorly and the extensor pollicis longus muscle toward the midline The capsule is opened exposing the scaphoid. To avoid excision of a normal carpal bone a skin clip is placed on the bone identified as the scaphoid, and an anterior posterior roentgenogram is made for confirmation Towel clips are placed on the fragment or fragments to be excised traction is exerted while the soft tissues are detached and the bone is removed.

After Treatment.—The wrist is maintained in a cock up splint for a period of two weeks. Active and passive motion and physical therapy are then rigidly enforced until function is restored

Bone Graft Operation

Soto-Hall attributes a high percentage of failures of the bone-grafting procedure to the use of this method in scaphoid fractures of long standing with the usual group of pathologic findings, viz. large and sharp pointed radial styloid, hypertrophic changes in the scaphoid and adjacent carpal bones, and narrowing of the involved articular surfaces In the presence of advanced osteoarthritic changes from a long standing nonunion any procedure which preserves motion in the wrist is likely to be followed by poor function. Other factors which entered into the poor results of bone-grafting procedures in the military service were the use of a single matchstick graft, blind bone-grafting procedures without excision of the interposed fibrous tissue, and inaccurate placement of the grafts Inadequate postoperative immobilization also contributed its share to the disintegration of the grafts, and the unsuccessful end results.

Bone grafts to the carpal scaphoid are indicated (1) when the ulnar fragment represents more than one-third of the carpal bone and the ulnar fragment is viable (2) when roentgenograms of the wrist reveal no arthritic changes. Murray and others will not agree with the first indication contending that

aseptic necrosis is an absolute essential for grafting thus providing both for union and for eventual revascularization.

Arthritic changes in the wrist joint are largely predicated upon wear and tear, and the elapse of time since the original fracture. Bone-grafting operations are perfectly justified if six months has elapsed from the time of the fracture without union. Of the cases reported by Murray 65 were of six months duration, or less. After one year arthritic changes may be sufficiently advanced to preclude bone-grafting procedures.

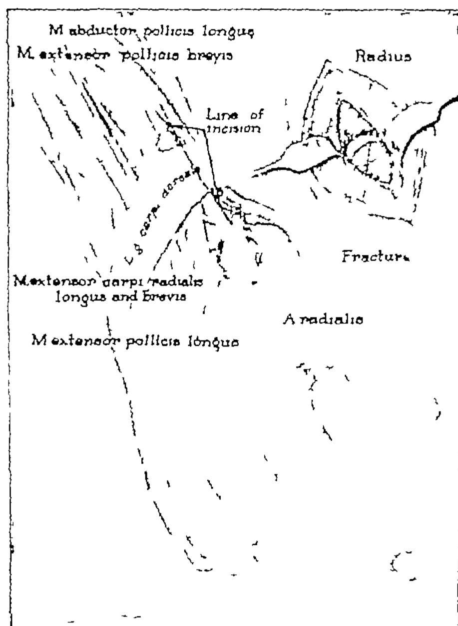


Fig. 503.—Technic of Soto-Hall and Haldeman for grafting ununited fracture of scaphoid bone. Approach exposing operative field. (From Soto-Hall, R., and Haldeman, K. O.: J. Bone & Joint Surg. 23: 841, 1941.)

Many types of bone grafting operations were developed during World War II. That utilized by Soto-Hall and Haldeman has several advantages. The procedure consists of complete exposure of the fracture site, removal of fibrous tissue, and the introduction of two rather substantial bone grafts. The existence

of a so-called "cyst" at the fracture site does not contraindicate the bone graft operation. The so-called cyst is composed of an area of fibrous tissue in the central part of the scaphoid which may be easily removed. By proper freshening of the fracture surfaces and elimination of this fibrous tissue, the prospect of a successful outcome is definitely enhanced.

Murray, who reported the technic described below in 1934, has recently (1946) surveyed 100 of his own cases. Ninety-six obtained bony union; of these the vast majority had good function of the wrist. These results cannot be passed over lightly. A summary of his opinions are as follows: (1) the graft must be large and so placed as to extend across the fracture well into the ulnar fragment; (2) the hole must not be drilled so as to violate articulations; (3) the fragments must be impacted in position by a tightly fitting peg; (4) adequate immobilization must be maintained until roentgenograms demonstrate union of the graft to both fragments, and trabeculations form across the fracture line. The minimum period of splinting is 10 weeks.

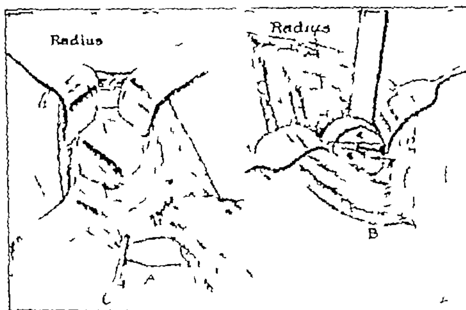


Fig. 604.—Same as Fig. 603. After excision of scar tissue, two holes are drilled into scaphoid bone. Position of drill checked by roentgenograms. Grafts removed from distal end of radius, tapped into holes. (From Soto-Hall, R., and Haldeman, K. O.: J. Bone & Joint Surg. 23: 841, 1941.)

Technic (Soto-Hall, Haldeman).—The scaphoid bone is exposed through an incision three inches in length, beginning at the distal end of the anatomic snuff box and continuing proximally above the carpal ligament. The bone is exposed by dissecting the capsule for a distance of about three-fourths inch from its radial attachment. The fibrous union is largely excised with a small bladed knife. With a ⅛ inch or 3/16 inch drill two holes are created, the entrances of the drills being as close to or in the extra-articular portion of the scaphoid as possible, i.e., the distal part. These holes can be placed closely together; in some instances a single point of entry is created distally, the drills being fanned in a V-shape at about 15 degrees. Position of these drills should be verified by roentgenograms, to be certain that they are in proper position and do not penetrate the semilunar bone.

Subsequently the incision is carried down lateral to the extensor pollicis brevis and the extensor carpi radialis tendons. From this area of the radius, with a sharp gouge or a V-shaped gouge, grafts are removed of a size commensurate with the holes in the scaphoid. The drills are then removed one at a time and the grafts tapped into place

Technic (Murray).—With the hand in full adduction, a curved incision two and one-half inches in length is made on the radial aspect of the wrist joint, the center of the incision being over the radial facet of the scaphoid the convexity of the curve should reach the abductor pollicis longus tendon. The radial nerve and vessels and abductor tendons of the thumb are retracted anteriorly and the extensor pollicis longus tendon is retracted posteriorly A small transverse incision is then made through the dorsal capsule of the wrist joint to the fracture line If the other bones of the carpus have not been injured, the fragments of the scaphoid will not be displaced and curettage will be unnecessary

After exposure of the most prominent point on the tuberosity of the scaphoid a small nick is made in the bone at this point to permit countersinking of the graft. Beginning at the nick a $\frac{5}{16}$ inch drill is passed through the proximal fragment, across the fracture line, and into the distal fragment. The drill should not come in contact with the semilunar facet of the scaphoid A bone peg slightly larger than the drill hole is removed from the tibia and driven into the hole and the protruding portion is severed

After Treatment.—Proper immobilization of the fracture following bone grafting procedures for nonunion is no less important than that for fresh fracture. The technic of plaster immobilization as advocated by Soto-Hall is as follows An anterior plaster splint is applied directly to the skin and fixed in place by a circular flannel bandage A circular cast is then applied extending well proximally on the forearm and incorporating the thumb to the middle of the nail The wrist is immobilized in full radial deviation, 160 to 150 degrees dorsiflexion and with the base of the thumb in full abduction, but with the metacarpophalangeal joint and the interphalangeal joints relaxed in slight flexion This latter position is obtained by pressure with the heel of the hand against the thenar eminence rather than by extension or abduction of the thumb with pressure against the tip or end of the thumb A new cast should be applied and the procedure repeated as required to maintain thorough immobilization of the fracture until union is solid

Soto-Hall sums up the end results of bone-graft procedures as follows, Some amount of stiffness persists after any bone grafting operation but the strength of the hand grip and other factors make the operation worth while in the properly chosen cases.

Arthrodesis of the Wrist

Obviously treatment which necessitates a stiff wrist must be advised reservedly Arthrodesis is primarily indicated for nonunion of rather long standing associated with a commensurate degree of arthritic change in the wrist joint. This procedure is to be particularly recommended for heavy duty wrists. Certainly by this means a stable and painless wrist joint may be insured. The technic of arthrodesis is described in Chapter XV

DIFFICULT AND UNUSUAL NONUNIONS
BRIDGING OF BONE DEFECTS

The vast majority of ununited fractures may be treated by the methods previously described, for those which present a more difficult or those wherein primary efforts to induce union by the simpler meth failed a more radical approach is indicated

The procedures subsequently described are suitable chiefly for tl of defects of the long bones, secondary to trauma, with or without i Technics for repair of defects following resection of the ends of the tumors will be found in the chapter on that subject and for congenita or congenital pseudarthrosis of the long bones in the chapter on Co Anomalies.

The majority of difficult or unusual nonunions may be classified i groups

Partial or Complete Bone Defects.—The procedures utilized for defects are technically difficult, healing is slower and the percentage o is usually more than following routine methods of treatment for sin union. For this reason, when shortening will cause relatively little disa in the upper extremity or if the defect is small the ends of the bone approximated and the usual technic for nonunion employed If this plished, the prospect of union is excellent under otherwise favorable co Shortening of one and one half inches of both bones of the forearm humerus is not incompatible with good function In the lower extremi ening of one and one-half to two inches is a definite handicap, and more is not permissible if it can be avoided The muscles and soft tissues o thigh, forearm and arm are capable of contraction to a degree which serve relatively normal muscular function within these limits of shorte

Simpler measures are also frequently applicable to partial bone de as much as one third of the circumference of the cortices can be ap residual defect is bridged by a single onlay bone graft, the interven being filled with cancellous bone.

Defects which do not fulfill the above requisites must be treate more difficult procedures subsequently described. Further, if one bo forearm is normal, it is preferable to bridge the gap in the affected bo than shorten the normal bone.

Nonunion Associated With Devitalized Sclerotic Fragments.—Th logic process develops most often in compound fractures with a previ bone infection. Most of these patients have already had an onlay type of graft which has failed to induce union between the sclerotic f Frequently the old infection has been exacerbated with each operat quality of the bone is so poor and the probability of a further react the infection so great that resection of the devitalized bone either i whole is more practicable Resection and bridging of the defect may plished as a single or a two-stage operation The two-stage plan may able if a reactivation of the infection is likely or if any plastic work o tissues is required After such a resection, these cases fall into the cla listed above, wherein the reconstruction problem is the bridging of complete bony defects.

Nonunion With a Short Osteoporotic Fragment.—Fortunately nonunion through the metaphyseal portion of a long bone is relatively uncommon, the large amount of cancellous bone in these regions tends to promote repair and regeneration Nonunions or defects in these regions present several reconstruction problems, since many are the result of massive injuries such as shotgun wounds or follow sequestration of large segments of bone incident to in

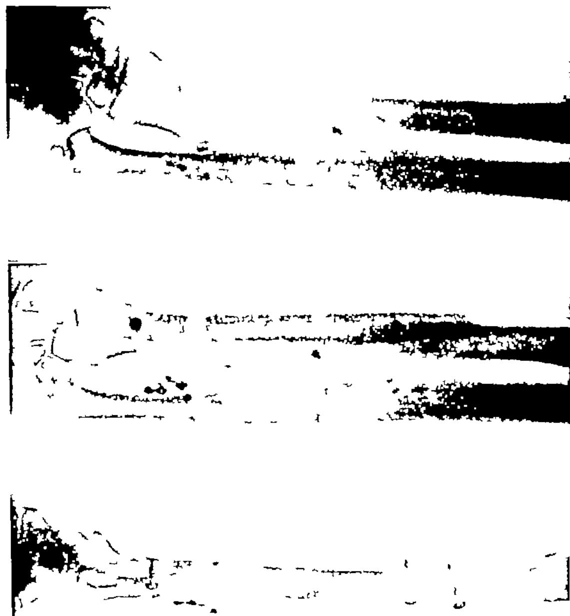


Fig. 505—Bridging of bone defect with whole fibular transplant. *A* Defect in radius secondary to shotgun wound. *B* Ten months after defect was spanned by whole fibular transplant, patient had 25 per cent range of motion in wrist, 50 per cent pronation and supination, 80 per cent of use of fingers, and could perform his usual duties as a farm hand.

fection. Scar tissue is frequently so extensive as to necessitate plastic procedures prior to any operation on the bone structure Some degree of ankylosis is present in the adjacent joint Preliminary reconditioning measures to improve the atrophic muscle and to mobilize the joint may be impossible. Finally, the fragment nearest the joint is short, and it is difficult to obtain firm mechani

cal fixation of the graft to this fragment This difficulty is increased by the osteoporosis usually present in the short fragment The normally thin cancellous portion of the short fragment may be reduced to a thin eggshell cortex the cancellous portion of the end of the bone may be partially absorbed and replaced by fat Since screws cannot be expected to hold in this soft bone, the ordinary measures are likely to be unsuccessful in securing adequate mechanical fixation

To the above classification could be added another group the loss of the entire extremity of a bone. With a few exceptions (Fig 643), the reproduction of the end of the bone by a structure which even approaches the normal anatomy is impossible In some cases, it is unnecessary (Fig 431) Certain segments of the skeleton are dispensable or partially dispensable In many cases, reconstruction procedures will improve function following the loss of an extremity of a bone.

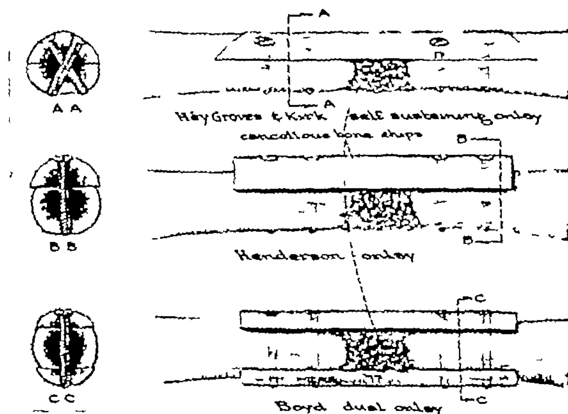


Fig. 566—A Hey Groves and Kirk technic. B Henderson onlay graft. C, Boyd dual onlay graft. (From Moore, J R. J Bone & Joint Surg 26: 463 1944)

BONE-GRAFTING TECHNICS FOR DEFECTS OR DIFFICULT NONUNIONS

A description of all of the technics which might be employed for difficult nonunions is obviously impracticable. The three basic procedures to be described, viz. whole fibular transplants dual onlay tibial grafts, and massive hemicylindrical grafts may be modified or combined with other routine bone grafting technics to cover almost any contingency

Whole Fibular Transplants

Whole fibular grafts provide an ideal means of bridging defects in the radius or ulna. The normal tubular structure of the fibula provides a graft

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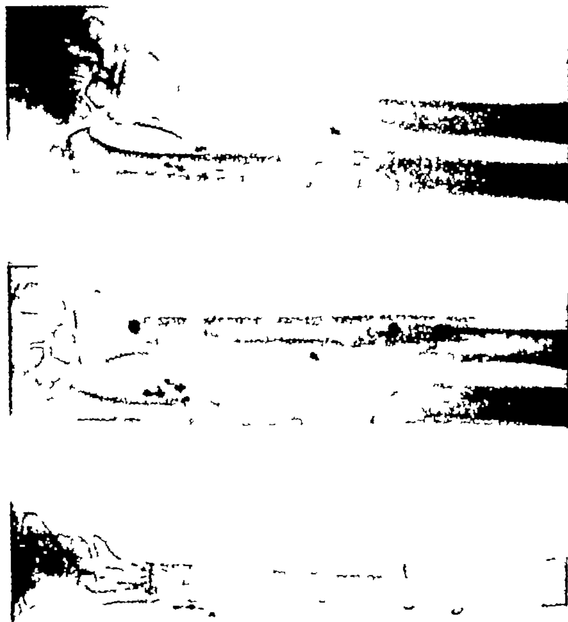


Fig. 605.—Bridging of bone defect with whole fibular transplant. *A* Defect in radius secondary to shotgun wound. *B* Ten months after defect was spanned by whole fibular transplant, patient had 25 per cent range of motion in wrist, 50 per cent pronation and supination, 50 per cent of use of fingers, and could perform his usual duties as a farm hand.

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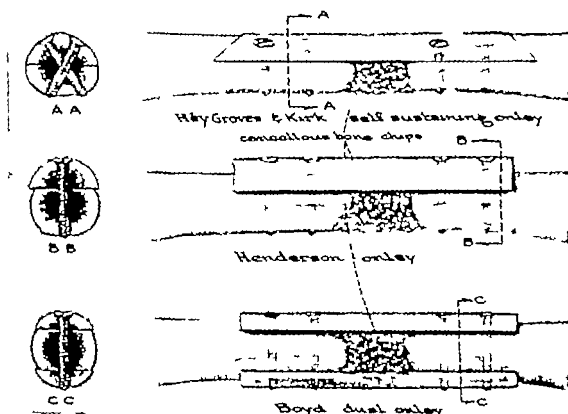


Fig. 564.—*A* Hey Groves and Kirk technic. *B* Henderson onlay graft. *C*, Boyd dual onlay graft. (From Moore, J R. J Bone & Joint Surg. 26: 45, 1944.)

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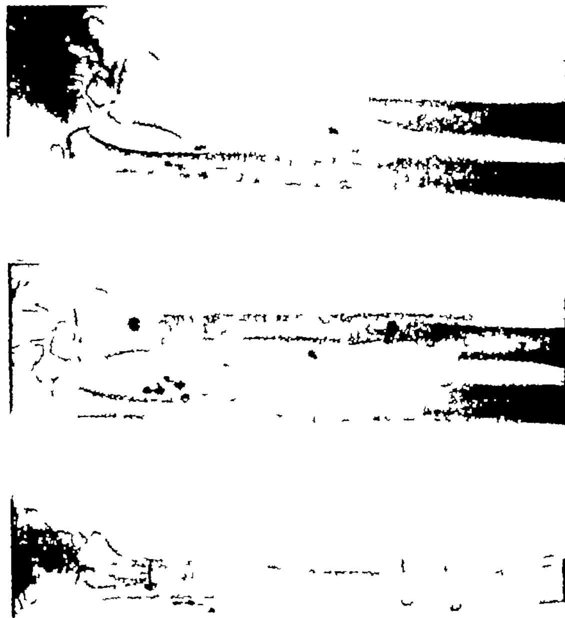


Fig. 665.—Bridging of bone defect with whole fibular transplant. A, Defect in radius secondary to shotgun wound. B, Ten months after defect was spanned by whole fibular transplant, patient had 25 per cent range of motion in wrist, 0 per cent pronation and supination, 80 per cent of use of fingers, and could perform his usual duties as a farm hand.

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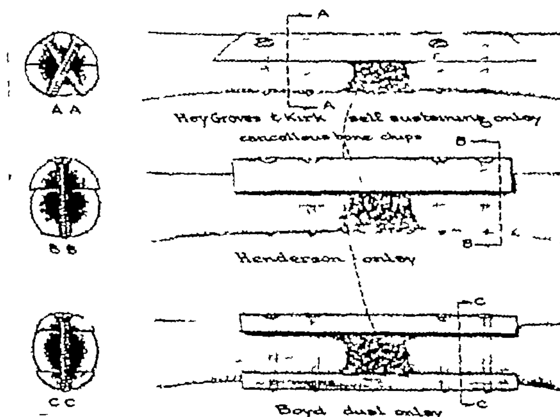


Fig. 506.—*A*, Hey Groves and Kirk technic. *B*, Henderson onlay graft *C*, Boyd dual onl graft. (From Moore J R. J Bone & Joint Surg. 26: 455, 1944.)

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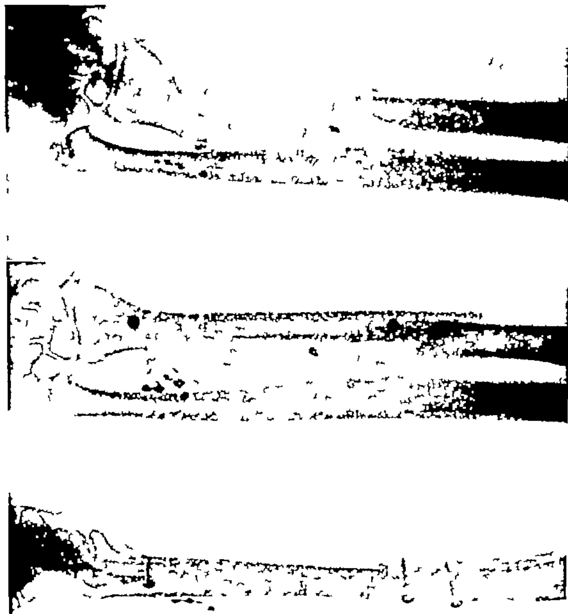


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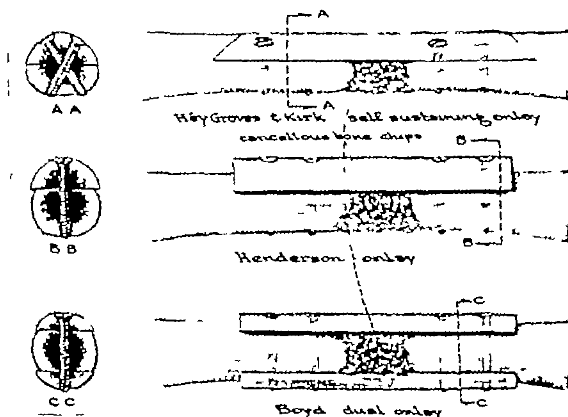


Fig. 806 — A Hey Groves and Kirk technic. B Henderson onlay graft. C, Boyd dual onlay graft. (From Moore, J R. J Bone & Joint Surg. 26 453 1944)

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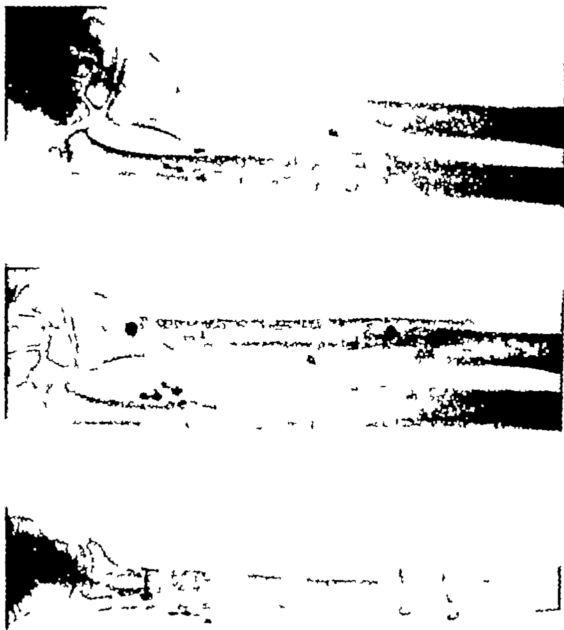


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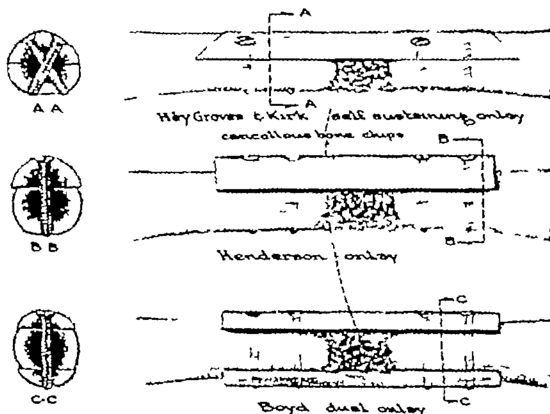


Fig. 504 —*A* Hey Groves and Kirk technic. *B* Henderson onlay graft. *C*, Boyd dual onlay graft. (From Moore, J R. J Bone & Joint Surg 26: 455 1944)

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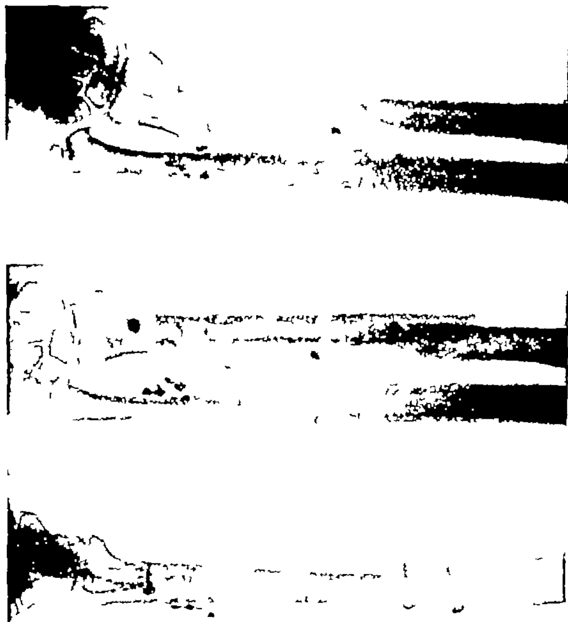


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the entire graft has been completely revascularized and replaced by living bone. As a consequence, some form of protection must be maintained for an indefinite time to prevent fractures of the graft. Preferably, this apparatus should be removable, or should contain joints which will permit active and passive motion and the routine physical therapeutic measures.

Dual Onlay Bone Graft

The advantages of dual grafts have been previously enumerated (p. 125). In the bridging of bone defects, the dual graft is especially applicable to complete defects of the shaft of the humerus and to fractures with a short osteo-

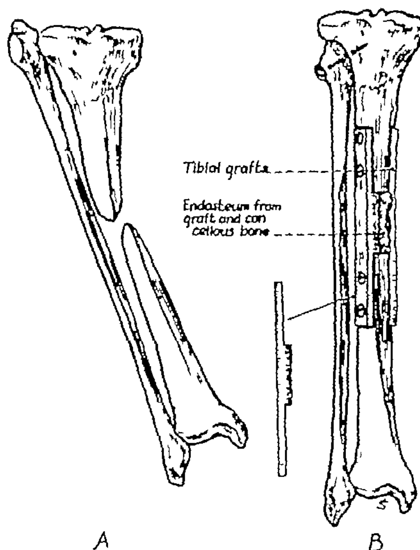


Fig. 407.—Boyd dual onlay bone graft. *A*, Defect of tibia with subluxation of fibula. *B*, After application of dual onlay bone graft and synostosis of proximal tibiofibular joint.

porotic fragment. In a femur with partial defects, the dual onlay graft is particularly efficient, providing sufficient strength during the period of revascularization, minimizing hourglass constriction, and increasing *the diameter of the* grafted bone. The partial absorption of one graft does not necessarily result in failure, as the second graft may maintain the internal fixation and permit adequate union.

Technic.—The defect in the bone is exposed and the bed and the bone fragments are prepared as described above. The most favorable location of

which is stronger than tibial grafts, with an equal amount of cortical bone. Since the cubic contents of the forearm are not materially increased, wounds may be closed with less difficulty This type of procedure is used routinely in the forearm unless the defect is near a joint, is relatively small, or is incomplete. The relative values of fibula and dual grafts are described in more detail in the chapter on Surgical Technic.

The size of the fibula limits its usefulness. Fibular grafts have been employed to replace defects in the shaft of the humerus and have taken satisfactorily As a rule, however the fibula cannot be expected to hypertrophy in an adult to the size of the shaft of the humerus. Since fractures through the graft are likely, we feel the procedure is contraindicated The fibular graft is used in the lower third of the humerus, though always in association with a substantial amount of iliac bone to recreate the broad expansion of the metaphysis.

In adults, fibular grafts should not be utilized to span defects in the tibia the fibula rarely hypertrophies sufficiently to withstand the normal stress and strain of weight bearing In children fibular grafts may be expected to hypertrophy until they approach the normal size and strength of the tibia. The degree of hypertrophy is more or less in proportion to the number of years of growth following the grafting procedure.

Technic.—Through an appropriate incision (Chapter IV) scar tissue is excised from the defect and the ends of the fragments are exposed An adequate vascular bed of surrounding soft tissues must be provided by this dissection The ends of the host bone are squared with a saw the resection being sufficiently extensive to eliminate sclerotic or aviable bone With a drill or curette, the medullary canals of the two fragments are reamed out While traction is placed on the extremity, the maximum amount of length that can be restored is accurately estimated

A fibular graft of proper dimension is next removed from the leg (Fig 111) The graft should be of sufficient length to span the defect and overlap the fragments of the grafted bone for a distance which will permit firm fixation. This graft is step-cut at both ends approximately half its circumference is thus preserved to be used as onlay grafts to the host bone. The intact central portion of the graft should be the exact size of the defect, so as to fit snugly when normal or maximum length has been obtained. Before insertion of the graft into the defect, the fragments of the grafted bone are flattened to receive the step-cut portions of the fibular graft. The fibular graft is then fitted into the defect and secured to both fragments of the host bone with metallic screws. The residual segments of bone from the step-cut are divided into multiple slivers and placed around the junctions of the fibular graft with the host bone. In lieu of or in addition to these fragments, iliac bone may be used.

In some cases it may not be possible to step-cut the fibular graft and insert one end as an onlay to a short fragment. Instead the intact fibular graft may be used as an intraosseous or intramedullary graft at one end, and as an onlay to the other

After Treatment.—After treatment is carried out as for routine non unions. One must realize however that considerable time is necessary for complete revascularization of a whole bone transplant Although the ends of the fragments may be united, stability and strength are not restored until

the entire graft has been completely revascularized and replaced by living bone As a consequence some form of protection must be maintained for an indefinite time to prevent fractures of the graft Preferably this apparatus should be removable, or should contain joints which will permit active and passive motion and the routine physical therapeutic measures

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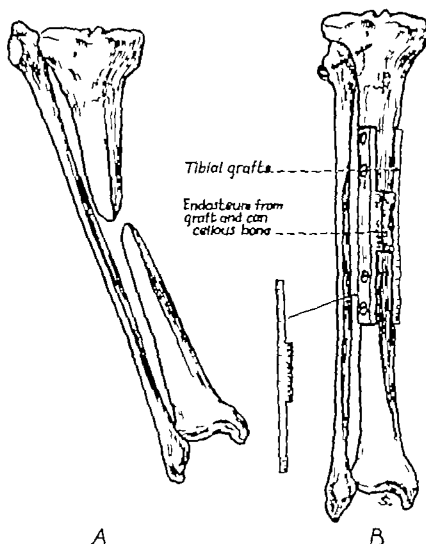


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Technic —The defect in the bone is exposed and the bed and the bone fragments are prepared as described above The most favorable location of

the graft is one which insures the least strain and the maximum bony contact with the host. One must consider the location of the grafts in relation to the optimum position for the mechanical insertion of the screws. In determining the size and length of the grafts the final soft tissue closure must be kept in mind. Two large cortical grafts materially increase the cubic contents of an extremity

The graft beds are prepared with a chisel by flattening out opposite sides of the fragments. No effort is made to inlay or countersink the graft, or to expose the medullary portion of the host fragments sufficient bone must be removed however to insure application of the graft to the fragments without angulation and without tension.

While the defect is being prepared, a second operative team removes a full thickness graft of the proper size from the tibia (p 127) Additional cancellous bone is removed from the upper end of the tibia with a curette. With a motor saw the cancellous surface of the graft is removed and preserved for future use The two grafts are then placed on opposite sides of the grafted bone and held in place by a bone clamp Minor adjustments may be made in alignment of the graft in relation to the host bone, and length of the extremity restored to the maximum degree. The application of the grafts may be facilitated by fixation *of one at a time. The first graft is held by two short, temporary screws* the second is then held in position by two screws which pass through both grafts and the intervening cortices of the fragments The short, temporary screws from the first graft are then removed and replaced by screws of sufficient length to transfix completely both grafts and the host bone The residual defect between the fragments and the trough between the grafts is now filled with the cancellous bone and the residual cancellous portion of the grafts. If necessary additional iliac bone may be used.

In bridging long defects, the cancellous bone attached to the portion of the tibial graft which spans the defect should be left intact (Fig 507) only the cancellous bone from the portion of the graft which overlaps the host fragment, *being removed.*

After Treatment.—See above

It should be emphasized again that, in weight-bearing bones, dual grafts must be protected for an indefinite period of time. These grafts revascularize slowly One of our failures occurred in a patient whose roentgenograms showed union and amalgamation of the grafts to the host fragment. After the patient had been walking without support for five weeks, the grafts fractured. Unprotected weight bearing should not be allowed until bony trabeculations bridge the defect. A properly constructed leather lacer brace will provide this protection and will allow the patient almost unrestricted activity during this long period of rehabilitation.

Hemicylindrical Apposing Massive Grafts

The massive apposing hemicylindrical grafts are based on principles outlined by Hey Groves and by Gill. The present technic is that developed by Flanagan and Burem By *apposing massive cylindrical grafts,* the tubular architecture of the bone at the site of the defect is reconstructed, thereby maintaining the continuity of the medullary canal and re-establishing tubular

strength In nonweight bearing bones because of their small size and their intended function these points are not particularly important. In the tibia and femur however especially in adults eradication of the defect by a strong tubular structure is a prime advantage The two apposing half cylinder grafts become firmly fixed to each other and to the host bone In essence this is a massive sliding type of graft, and thereby possesses some of the inherent weaknesses and advantages of all sliding grafts.

The advantages are as follows

1 Complications associated with the removal of grafts from the opposite extremity are avoided, thus permitting early ambulation on a sound extremity This is not a major consideration in the lesser bone grafting operations, in bridging defects however, the removal of a massive homogenous graft, particularly for dual bone grafting procedures for the larger bones, is a major surgical procedure and the period of disability in the donor extremity is frequently prolonged and sometimes permanent.

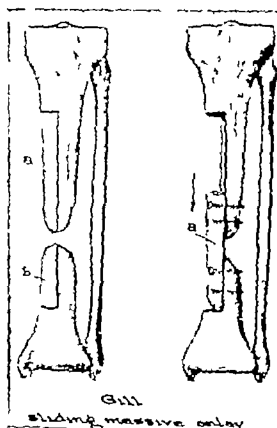


Fig. 501.—Gill massive sliding graft. (From Moore, J R. J Bone & Joint Surg 26: 445, 1944.)

2. In proportion to its size, the strength provided by the tubular structure is considerably more than that of a comparable amount of bone utilized as a dual graft.

3 The cubic contents of the extremity are not increased, and closure is thus accomplished with less tension.

4. Restoration of the tubular structure of the bone at the defect minimizes the possibility of hourglass constriction.

5 An excessively long defect may be bridged with bone of substantial dimensions. To remove the same amount of bone from the opposite tibia would impose too great a burden of repair on the normal extremity.

The disadvantages of this procedure are as follows

1. The technic particularly for the femur is an undertaking of considerable magnitude. A maximum amount of surgical trauma is imposed upon one locale. Obviously the patient must be in proper condition to withstand a prolonged procedure and one attended by hemorrhage trauma and shock.

2. Since one-half the continuity of the bone is utilized as a graft interruption of the tranquil process of healing by infection or other causes assumes catastrophic significance. After extrusion of the grafts, little is left for any subsequent reconstruction procedures, and failure may mean amputation.

For the above reasons, this technic should never be utilized if less hazardous methods can accomplish the same result.

We have utilized the Flanagan and Burem technic for bridging the larger defects in the tibia and femur and have found it most satisfactory. If the defect is less than two and one half inches in length massive apposing hemicylindrical grafts are employed. For defects larger than two and one-half inches a single hemicylindrical sliding graft is sufficient, the residual half being filled with supplemental grafts from the ilium.

In our experience the procedure is also suitable for nonunions with relatively small defects but associated with extensive sclerosis of both fragments. The creation of a large defect by resection of the devitalized bone followed by the Flaganan Burem technic has been more successful than measures previously employed at the clinic. If there is a grave probability of relighting the infection, the operation is best performed in two stages.

All of the preliminary considerations prior to bone grafting are particularly applicable to this procedure (p 613). The dimensions and locations for the grafts and the architecture of the procedure should be well planned from preoperative roentgenograms.

Massive Apposing Hemicylindrical Grafts for Defects of the Tibia

Technic (Flanagan and Burem).—The entire length of the shaft of the tibia is exposed by a routine incision (p 171). The periosteum is elevated well above and below the defect all scar tissue is excised at the fracture site and the ends of the bone are freed and mobilized. The ends of the fragments are resected proximally and distally all poorly nourished or avascular bone being eradicated, and the ends are squared with a hand saw at a right angle to the longitudinal axis of the bone. Thereafter longitudinal traction is applied to the extremity and the pattern and length of the bone grafts are planned to conform to the size and location of the defect. For a tibia of relatively normal length with a defect of two and one-half inches or less, the grafts are cut as illustrated in Fig 509A for defects of the middle third, for defects of the junctions of the middle and adjacent thirds as in Fig 509B and for defects in the proximal or distal thirds as in Fig 510A. If the tibia or femur is short or the defect of more than two and one-half inches, apposing half-cylinder grafts can

not be used In these cases, a single half-cylinder sliding graft may be used to bridge the defect the opposite half of the defect being filled with a block of iliac bone or with iliac chips.

Extreme care and patience must be exercised in all Z-plastic or step-cut procedures, first, to preserve the blood supply to the intact portions of the tibia, and second to avoid breaking the sound portion of the bone at the level of the crosscut, or producing longitudinal splits of the shaft of the bone into adjacent joints. The actual execution of these steps are most difficult, particularly the division of the posterior cortex. The grafts are removed in the following manner the graft sites are exposed subperiosteally, the periosteum and muscle attachments on the sound portion of the shaft being carefully preserved Longitudinal cuts of the anterior cortex are made with a motor saw Holes are then drilled in the line of the crosscut at each end and joined with a narrow thin osteotome The crosscuts must be completed before longitudinal division of the posterior cortex is attempted Multiple holes are next drilled through the posterior cortex in the line of the anterior cut and the posterior cortex is divided with an osteotome and a mallet During this procedure no attempt should be made to pry the graft away from the sound segment of the bone, else the bone may split or fracture in an undesirable location, despite the preliminary precaution of completing the transverse cuts.

The grafts are rebedded according to the plan outlined in the accompanying illustrations, and firmly fixed by means of transversely placed screws. Defects at the donor site are filled with iliac blocks or chips, thus facilitating osteogenesis in these areas.

After Treatment.—A plaster cast is applied from the iliac crest to the toes on the affected side and immobilization is maintained for a period of ten weeks. Thereafter a long leg walking plaster is applied. A long leg brace may be substituted for the walking plaster at the end of four and one half to five months, depending upon the progress of healing The routine measures to mobilize the joint and recondition the musculature of the extremity are instituted at this time.

Massive Apposing Cylindrical Grafts for Defects of the Femur

The carpentry of the procedure for the femur follows essentially the same pattern as that described above for the tibia. The exposure of the femur is in itself an extensive operation and attended by considerable hemorrhage Superimpose upon this the exact carpentry of the technic on the bone and one indeed has a procedure of maximum magnitude General preparatory measures (Chapter I) must be carried out meticulously and thoroughly and the affected extremity must be reconditioned (p 613) by every possible means.

In the femur particular caution is necessary in lining up the fragments after removal of the grafts, and in the process of rebedding and realigning the grafts with the sound fragments Since the distal end of the extremity is under the control of an assistant and the extremity is heavy a fracture of one limb of the crosscut is much more easily produced than in the tibia.

In the experience of Flanagan and Burem the use of iliac bone to fill in the residual donor site of the reconstructed femur is far less necessary than in the

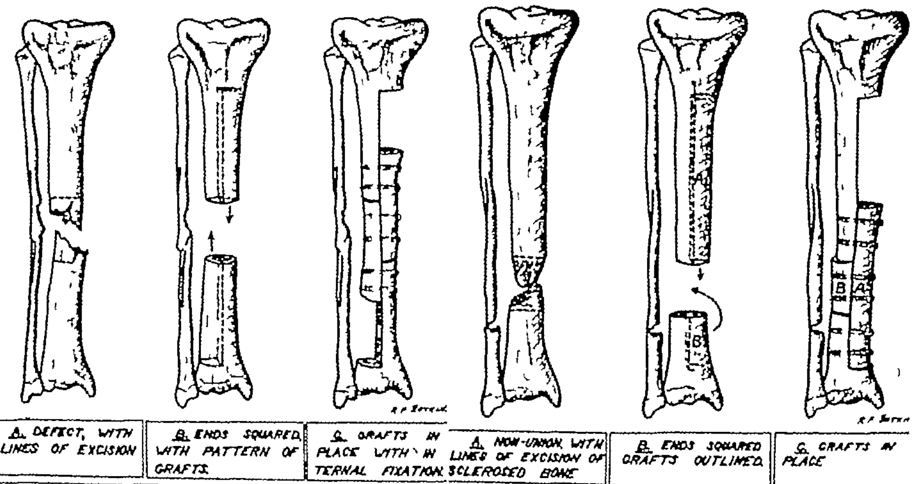


Fig. 599.—Massive apposing hemicylindrical grafts (Flanagan and Burem). A, Technic applicable to defects in middle third of tibia. B, Procedure for defects at junction of middle and adjacent thirds. (From Flanagan, J. J., and Burem, H. S.: J. Bone & Joint Surg. 29: 657, 1947.)

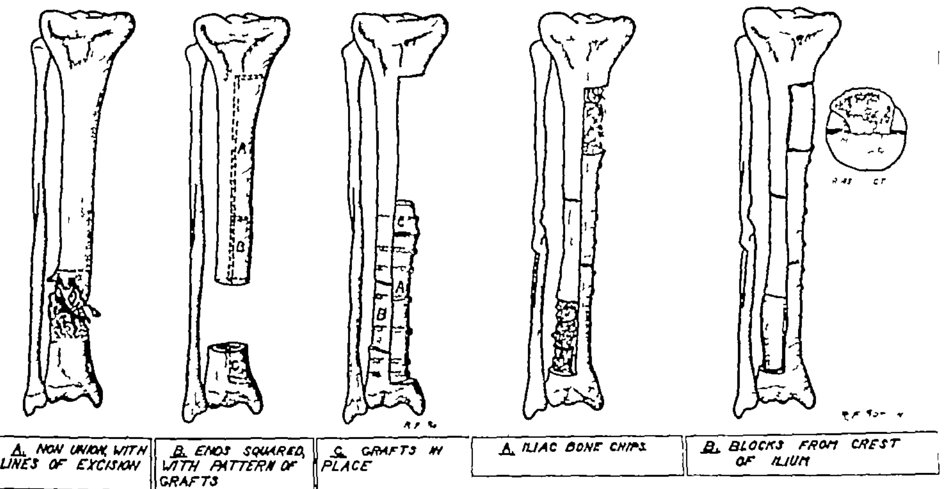


Fig. 510.—Same as Fig. 509 A, Massive cylindrical grafts as applied to defects in upper or lower third of tibia. B Iliac bone used to fill residual defects. (From Flanagan, J. J., and Burem, H. S. J. Bone & Joint Surg. 29: 587, 1947.)

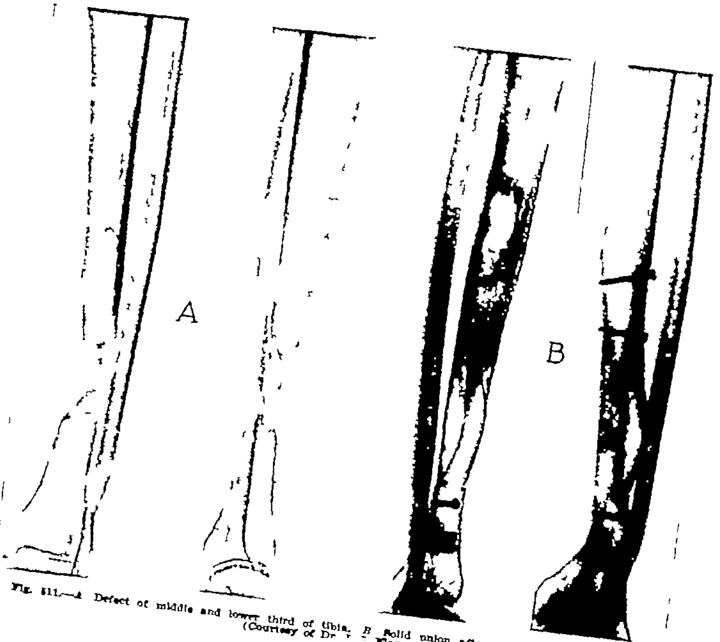


Fig. 411.—A, Defect of middle and lower third of tibia. B, Solid union after massive hemicylindrical graft. (Courtesy of Dr. [illegible] Flanagan.)

tibia The abundant blood supply of this bone promotes regeneration more rapidly The use of iliac bone for the femur is primarily indicated when only a single half cylindrical graft is used In such cases, supplemental iliac bone bridges the opposite half of the defect

After Treatment.—A double spica cast is applied from the nipple line to the toes on the affected side and to the knee on the opposite side and maintained for a period of twelve weeks. Thereafter, the plaster is removed and the affected extremity is placed in balanced traction to facilitate mobilization of the joint and reconditioning of the muscles Walking in a brace is permitted only after regeneration and union is practically complete



Fig. 612.—Comminuted fracture of middle third of femur with large defect, treated by massive cylindrical graft. (From Flanagan, J J., and Burem, H. S. J Bone & Joint Surg 29: 587 1947)

DEFECTS OF THE FIBULA

Since defects in the shaft of the fibula are intentionally created by the removal of fibular grafts a nonunion, or traumatic defect of the fibula is of little practical importance All of the fibula except the lower three inches, may be dispensed with and little or no disability will follow consequently no repair is required.

The lower three inches of the fibula however is an important structure necessary to the normal function of the ankle. We have never had an occasion to replace the lower end of the fibula because of defects from traumatic injuries

or infections A modification of the Carroll technic, whereby the upper third of the fibula is used to replace the lower third, has been utilized when resection of the lower end was necessitated by a benign tumor (Ch XIX)

DIFFICULT NONUNIONS OR DEFECTS OF THE TIBIA

In many nonunions of the tibia with no actual bone defects, the fragments are sclerotic for some distance on each side of the fracture site. Experience has shown that, in a high percentage of these cases, union may be obtained by resection of the minimal amount of bone necessary to freshen the ends, followed by the application of a single or dual onlay bone graft. After osteotomy of the fibula defects of less than one and one-half inches may be closed by approximation of fragment ends.

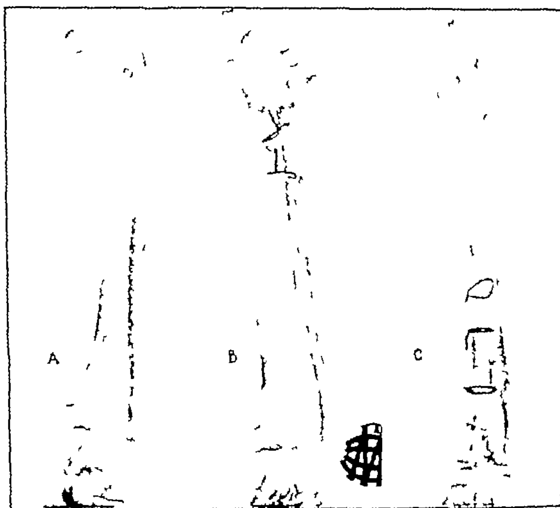


Fig. 613 — *A* Defect of tibia following osteomyelitis, in child four years of age. *B* Fibula has been transplanted and fixed to proximal fragment of tibia. Note callus bridging defect between fragments of fibula. *C* One year and nine months, respectively, after first and second stages of transplantation of fibula to tibia. Graft has hypertrophied, defects proximally and distally between fibular graft and fragments of fibula bridged by new bone.

Partial defects of the tibia, *wherein the cortex can* be approximated on one side, may be bridged by a single graft or by dual grafts, the intervening space being filled with cancellous bone from the ilium. Union of the fracture and complete filling in of the defect in this type of reconstruction is a rather slow process nevertheless, the procedure is preferable to the more complicated operations for bridging of large bone defects.

In the presence of defects of more than one half inch, or of sclerosis so extensive that the simpler procedures are not feasible, dual onlay bone grafts (p 625), or massive hemicylindrical sliding grafts (p 710) may be employed

Defects of the tibia in children, secondary to osteomyelitis or trauma, are treated in a different manner The fibula of the affected extremity is utilized in preference to a graft from the opposite tibia, the operation being carried out in two stages. Thus, the blood supply at one end of the transferred bone is always active, and the prospect of success commensurately better The technics to be described are not applicable to congenital pseudarthrosis or nonunion following operations for congenital bowing of the tibia (Chapter XXV)

Transference of the fibula to replace the tibia was originally conceived by Hahn in 1884 and subsequently perfected by Codivilla Hahn transferred only the distal fragment of the fibula into the proximal end of the tibia In order to eliminate the resulting valgus deformity of the foot, Codivilla also transplanted the lower end of the fibula into the distal fragment of the tibia, thus restoring the osseous continuity in the longitudinal axis of the leg

Huntington, in 1905 reported a case wherein a five-inch gap in the shaft of the tibia occurred following osteomyelitis Repair was accomplished by a two stage procedure

Technic (Huntington)—First Stage.—The fibula is exposed on a level with the lower end of the upper tibial fragment and denuded The proximal fragment of the tibia is approached through a separate incision, the end freshened, and a cup-shaped depression formed therein. The fibula is then transplanted beneath the anterior flexor group of muscles into this depression The fragment should be stabilized by some form of internal fixation.

After Treatment.—With the knee in slight flexion a cast is applied from the groin to the toes, then bivalved to allow for swelling Three weeks later this cast is replaced by one similar but more closely fitting which is retained for eight to ten weeks. If union is solid at the end of that time, the second part of the procedure may be carried out otherwise immobilization is continued in a third cast.

Second Stage.—The skin should be prepared (p 4) two or three days prior to operation to reduce the danger of infection of the wound.

The lower portion of the fibula is exposed on a level with the upper portion of the distal tibial fragment and denuded. The lower tibial fragment is reached through a separate incision the end freshened, and a depression made in the end of the bone for reception of the fibular fragment The distal end of the fibular fragment is then transplanted beneath the flexor group of muscles into the end of the tibial fragment and stabilized by some form of fixation.

After Treatment—The after treatment is identical with that described above until union is solid. At that time the knee is placed in extension and a leather lacer brace is applied from the groin to the ankle. A rigid joint is attached at both the knee and ankle and weight bearing is begun. After one month free motion is permitted at the knee and ankle and active exercises and physical therapy particularly of the knee are instituted.

In 1907 Stone reported a technic of transplantation of the fibula for a defect which extended from just proximal to the lower tibial epiphysis to the

junction of the middle and upper thirds. This was also performed in two stages. The second stage was carried out five and one half months after the first.

Technic (Stone).—First Stage.—A three-inch longitudinal incision is made over the lower end of the upper fragment of the tibia and the muscles are separated along the interosseous membrane until the fibula is exposed. The lateral side of the fibula is approached through a separate incision and the bone is divided with a Gigli saw; in order to gain length, if possible, the division should be made at a level slightly proximal to the end of the upper tibial fragment. A mortise is next cut into the tibia and the fibula is inserted into this groove. The reflected periostei of the tibia and fibula are then sutured together to maintain close apposition.

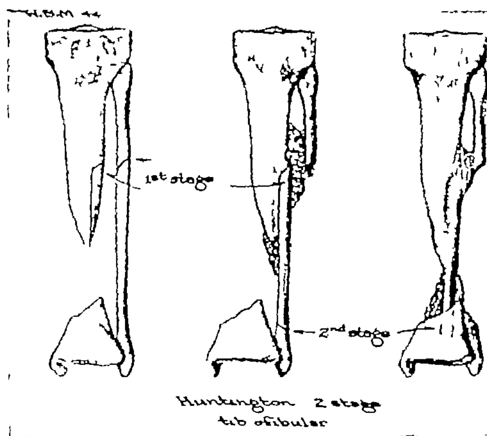


Fig. 514.—Transplantation of fibula to replace defect of tibia (technic Huntington). *A*, Defect of tibia. *B*, Upper end of fibula grafted to proximal fragment of tibia. *C*, After solid union proximally, distal end of fibula transplanted. (From Moore, J. R.: J. Bone & Joint Surg. 26: 455, 1944.)

After Treatment.—(See p. 717.)

Second Stage.—An anterolateral incision is made over the upper end of the lower fragment of the tibia and by careful dissection, the lower end of the fibula is exposed through the same incision. With a chisel, the fibula is split horizontally a distance of four inches, separation of the periosteum from either half of the bone being avoided. At the lower end, the inner half of the bone is cut transversely at the level of the upper part of the remaining lower tibial epiphysis and the outer half divided at the proximal end of the cut. A depression is then formed in the tibial fragment and the inner half of the

fibula transplanted into this cup The outer half of the lower fragment of the fibula is held in place by the periosteum, thus the fibula continues to perform its function in relation to the ankle joint

After Treatment.—Immobilization is maintained for a period of four months. At that time union should be sufficiently solid to permit resumption of unrestrained active use of the extremity

Since the distal portion of the extremity tends to rotate inward, varus deformity is frequently associated with defects of the tibia This levers the upper tibio-fibular joint apart, causing subluxation and marked prominence of the head of the fibula Correction of this deformity suggested the following procedure to Campbell in 1919

Technic (Campbell)—An incision three inches in length is made over the lateral aspect of the fibula After identification and retraction of the peroneal nerve the head of the fibula is freed by severance of its ligamentous and capsular attachments, and all cartilage and soft tissues are removed. A cavity is then created on the external condyle of the tibia for reception of the denuded head of the fibula By traction and angulation, the fibula is reduced within this cavity under tension, to insure maintenance of its position The periosteum of the fibula and tibia are then sutured together At the same operation or at a later date a massive inlay or onlay graft is employed to bridge the defect between the fragments. (We would now employ a homogenous dual onlay graft from a relative or from the bone bank.)

By this procedure the normal contour of the leg is restored and the defect of the tibia repaired without interrupting the continuity of the fibula. If the defect is large or the tibial fragments sclerosed however the Huntington technic is preferable

DIFFICULT NONUNIONS OR DEFECTS OF THE FEMUR

In the first edition, Campbell made the following statement regarding the femur "The technic is dependent entirely upon the size of the defect If this is less than two and one-half inches in length, the fragments should be approximated and an onlay bone graft operation carried out Although two and one-half inches' shortening is sufficient to produce material disability the prospect of success by this method is far better than by an attempt to preserve the length and bridge the defect with a graft." With improved technics of grafting and internal fixation we feel that under ordinary circumstances, not more than one and one-half to two inches of shortening is permissible If more than this amount is present, procedures for bridging of defects are applicable. For partial defects the dual onlay bone graft is utilized. For bridging of complete defects, the massive hemicylindrical sliding graft is preferred (p 711)

DIFFICULT NONUNIONS OR DEFECTS OF THE HUMERUS

Defects of the shaft of the humerus are more easily repaired, as a rule than those of any other long bone Since a considerable amount of shortening is commensurate with function, treatment may usually be carried out by the onlay bone-graft technic, the ends of the bones being brought into contact. Should preservation of the length of the humerus be desired the defect may be bridged by a dual onlay bone graft (p 625)

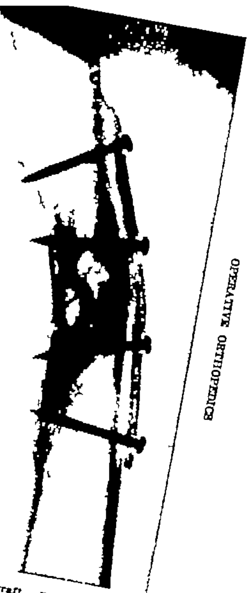






Fig. 515.—*A*, Defect of femur with conical-shaped end eradicated partially by shortening, and by application of a dual graft. *B*, Fracture sustained through graft when patient began unsupported weight-bearing too early. With further immobilization, union took place. *C*, Three years after dual graft.



Fig. 516.—*A*, Defect of upper third of humerus following compound infected fracture with sequestration. Insert shows appearance six weeks after application of dual grafts. *B*, At three months, there is beginning sequestration of medial graft, secondary to infection. *C*, Despite loss of one graft, defect is satisfactorily bridged at seventeen months.

The dual onlay bone graft is also applicable to defects of the upper thir of the humerus wherein the short proximal fragment is extremely osteoporoti (Fig 516) The technic for this region is essentially the same as that used fo ununited Colles fractures (p 727)

Defects of the metaphyseal portion of the humerus, if less than two inche in length, are best overcome by apposition of the condyles to the shaft and bridg ing of the fracture by a cortical graft extending from the shaft of the humeru onto the posterior aspect of the external condyle. If the defect is too large t permit apposition of the fragments, a whole fibular transplant is utilized in muc



FIG. 517.—*A* Large defect in metaphyseal portion of humerus, following compound fracture with sequestration of a large segment of bone. *B*, Twenty months after bridging of defect by a whole fibular transplant. Cancellous bone utilized to bridge expanded portion of metaphysis and shaft.

the same manner as for the forearm bone defects. The distal end of the graft is applied to the condyle with the longest metaphyseal portion though prefer ably the external condyle The distal fragment must be sufficiently large to allow engagement by two screws A generous amount of iliac bone is utilized to restore the normal metaphyseal expansion This operation is carried out through a Campbell posterior approach (p 162) During the entire procedure the elbow must be maintained in a more or less constant position, until final immobilization is secured with a plaster cast and an abduction humerus splint.

DIFFICULT NONUNIONS OR DEFECTS OF THE RADIUS AND ULNA

Defects of the proximal third of the radius, or the distal two to three inches of the ulna are treated by excision of the small fragments. These segments of bone are not indispensable, and their removal is far simpler than procedures for restoration of the continuity of the bone The treatment of ununited fractures of the proximal end of the ulna have been previously described (p 694)

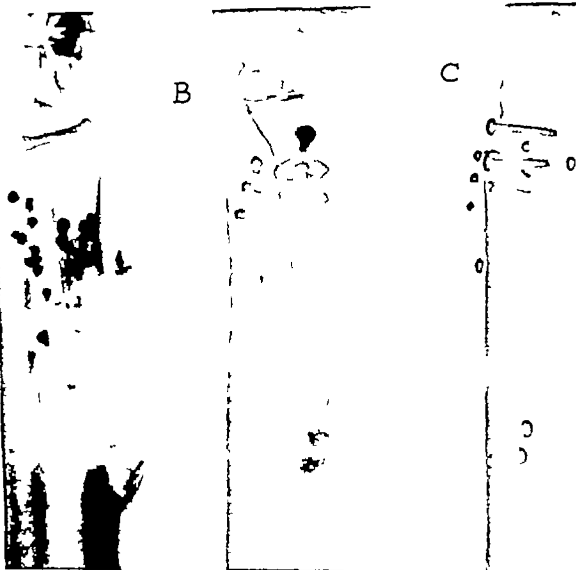


Fig. 518.—*A* Defect in radius secondary to shotgun wound. *B* Ten months after bridging of defect by whole fibular transplant. Distal end of ulna resected to compensate for disproportion in length.

Measures described for congenital absence of the radius (Ch. XXV) may be *modified to apply to large defects of the distal two-thirds of the shaft.* Hey Groves and Watson-Jones have reported an operation for such a lesion wherein the distal end of the ulna was transferred into the remains of the distal fragment of the radius. The ulna should be sufficiently short to allow correction of the radial deviation of the hand This procedure of course limits pronation and supination but both appearance and function are materially improved (See also "Resection of the Distal End of the Radius With Repair by Fibular Graft," Ch XIX.)

Defect in Both Bones.—Usually length may be equalized or aviable bone may be eradicated by resection of the fragment ends well within a permissible limit of shortening. Under these circumstances, single or dual onlay bone grafts are adequate. If excessive shortening would be produced by this procedure, each bone must be attacked separately. Following a previous infection in one or the other, the uninfected bone should be operated upon first and the reconstruction carried out as a two-stage procedure. Whole fibular transplants (p. 705) may be employed.

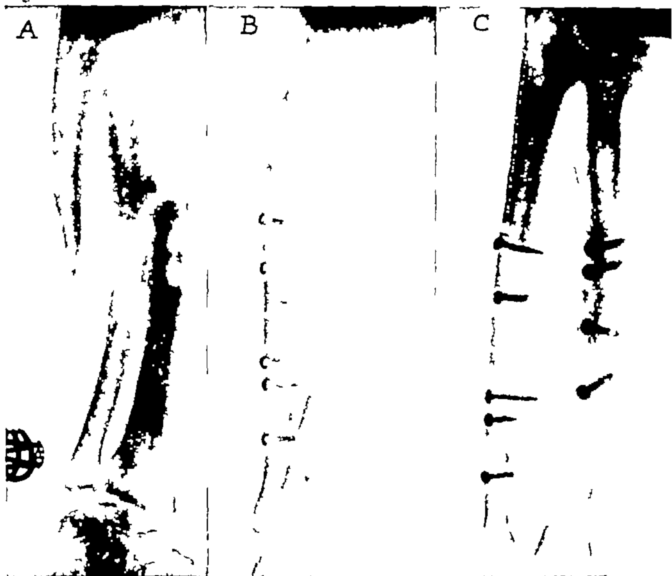


Fig. 519.—*A*, Old compound fracture with defect of ulna and nonunion of radius. Failure to obtain union elsewhere; exacerbation of infection with each operation. Forearm grafted in two stages. *B*, After bridging of defect in ulna. *C*, After onlay graft to radius.

Defect in One Without Shortening or Malalignment of the Other.—A defect from a previous loss of bone, or from resection of eburnated bone cannot be closed because of the splinting of the normal bone. Only under rare circumstances should the continuity of the normal bone be jeopardized by osteotomy in order to permit apposition of the affected bone fragments. Rather than shorten the normal bone and subject the latter to the danger of nonunion, large

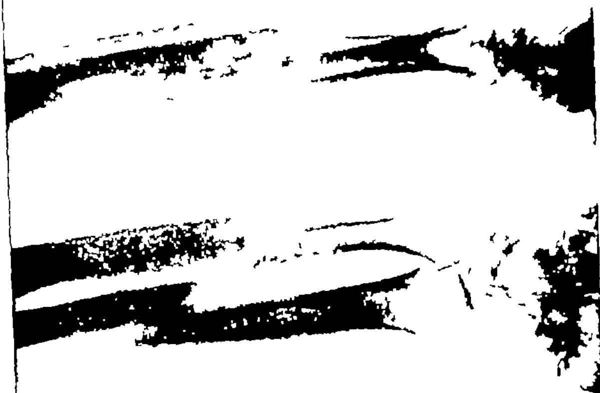


Fig. 520.—Defect in ulna with overlapping of radius.

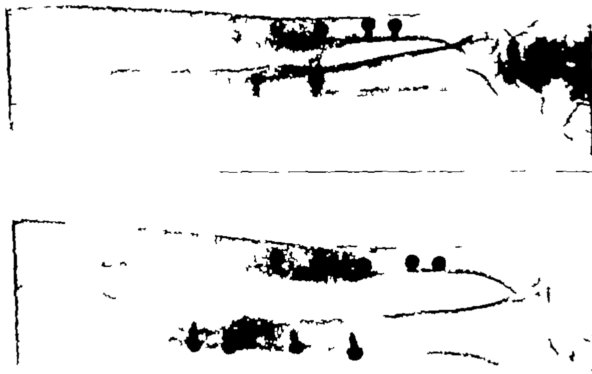


Fig. 521.—Same as Fig. 520. Overlapping segment of radius resected and used to fill defect in ulna. Single onlay bone graft holds free segment of radius between fragments of ulna.

defects should be spanned by fibular grafts (Fig 518) Shorter defects may be spanned by dual onlay grafts.

Defect in One With Overlapping or Malunion of the Other—The maximum length which may be restored to the forearm by reasonable traction is determined. The fragments of the overlapping bone are cut to permit end-to-end apposition and the excess portion is used to fill the defect in the opposite bone The section of the overlapping bone must be carefully cut so as to insure a proper fit into the gap in the opposite one after the ends of the latter have



Fig. 522.—Failure elsewhere to obtain union by use of metal plate. Attempt to compensate for defect in ulna by resection of head of radium.

been resected and squared to receive the transplant. Thereafter single onlay cortical grafts are applied to both bones. Obviously the carpentry of this procedure must be exact for accurate fit and alignment of all of the parts involved. The fact that three fracture sites, rather than the usual two, remain to unite is a disadvantage On the other hand, undue shortening of the forearm would produce relaxation of the soft parts, thus preventing satisfactory action of the forearm muscles. Following the above procedure the transplant would certainly fare badly in the presence of an exacerbation of infection or a

postoperative infection and is justifiable only if the soft tissue investment and the physiologic status of the fragments is most favorable

In the presence of a disabling malunion of one bone associated with a defect of the other the malunited bone may be justifiably divided the ends resected, and a bone graft applied If shortening is not excessive sufficient bone may be removed to permit approximation of the defect in the opposite bone otherwise the technic may be carried out as described above, or the defect may be bridged by a whole fibular graft



Fig. [illegible].—Same as Fig. [illegible]. Resected segment of radius used to span gap in ulna. Onlay bone graft spans the two fractures and holds whole bone transplant in proper position. Beginning union at nine weeks.

UNUNITED COLLES FRACTURE

If the distal fragment is fairly well preserved the technic for malunited Colles fractures (p 578) may be applicable As a rule the distal fragment is short and osteoporotic, in this event the dual onlay bone graft is particularly advantageous. The procedure is carried out as follows Through an appropriate dorsal incision, the distal end of the shaft of the radius the fracture site and the distal fragment are exposed Fibrous tissue is removed from the ends of the fragments, and the ends are freshened. In this process, meticulous care must be exercised else the distal fragment may be crushed, this fragment is too fragile to permit scarification or flattening of its thin, cortical walls to a

material degree Dual, thin, cortical grafts are applied on each side of the distal fragment, and are transfixed to the fragment by one screw If the fragment is too small to allow the insertion of even one screw, the clamp-like action of the dual grafts provides adequate fixation. The distal screw should not be tightened until it crushes the fragment. The proximal ends of the graft are then transfixed to the proximal fragment by two additional screws. Any intervening space between the distal and proximal fragments and the dual graft is filled with cancellous bone (Fig 450)

The after treatment is carried out as for Colles fracture, though immobilization is continued for at least six to eight weeks.

DEFECTS OF THE METACARPAL BONES

Morris utilizes a mortise and tenon type of graft from the tibia to fill defects between the head and base of a metacarpal bone

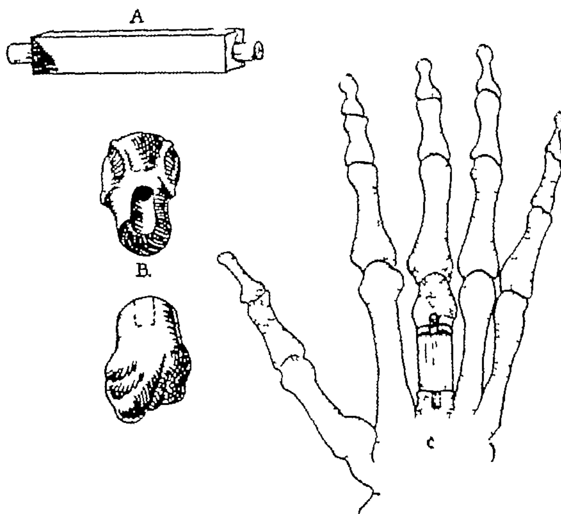


Fig 454.—Morris technic of spanning defect in metacarpal bone with tibial graft. Tenons cut in ends of graft to fit into mortise in distal and proximal metacarpal fragments. (From Morris, H. D Surgery 19 364 1946)

Technic (Morris) —The involved metacarpal bone is exposed by a dorsolongitudinal incision and the scar tissue is excised from about the fragments. The fractured surfaces of the proximal and distal fragments are then resected

to form a transverse surface The medullary canal of each is reamed with a drill and a curette for a distance of approximately 1.5 cm Traction is exerted on the digit at the distal end of the ray and the proper length of the tibial graft is determined This graft is of sufficient length to bridge the defect and to present a tenon 1.5 cm in length on each end The tenon ends of the graft when rounded should be approximately the same diameter as the cavity created in the fragments of the metacarpal bone Rather than exert excessive traction for the placement of the tenons in the mortises, a slot is cut on the dorsal aspect of the distal fragment The proximal end of the graft is inserted into the medullary canal of the proximal fragment and the distal end of the graft is inlaid in the slot of the distal fragment The graft is held in the slotted distal fragment by means of a stainless steel wire suture

After Treatment.—See p 599



Fig. 526.—Defect of mandible. A Repair by inlay graft from tibia.

DEFECTS OF THE MANDIBLE

The repair of residual defects from sequestration of large segments of the mandible is exceedingly difficult Because of the preponderance of avascular scar tissue and, frequently recurrence of a dormant infection even the most skillfully executed bone-grafting technic may be followed by sequestration or absorption of the graft and a consequent return to the former status. Large defects of the ramus and angle or body of the mandible are bridged by rib

grafts (see Congenital Anomalies of the Mandible, Ch. XXV) or curved grafts removed from the wing of the ilium Smaller defects are treated by bone grafts, as described for nonunion of the mandible (p 684)

References

Abbott, L. C.: The Use of Iliac Bone in the Treatment of Ununited Fractures, Am. Acad. Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Mich., 1944 J W Edwards.

Adams, J D., and Leonard R. D Fracture of the Carpal Scaphoid: New Method of Treatment, With a Report of One Case, New England J Med. 198 401 1928.

Albee, Fred H. Bone-Graft Surgery Philadelphia, 1915 W B. Saunders Co.

—: Treatment of Ununited Fracture of the Neck of the Femur Surg Gynec. Obst. 48 810 1929

—: Principles of the Treatment of Non Union of Fracture, Surg Gynec. Obst. 51 289 1930.

— The Various Uses of the Bone Graft, Proc. Roy Soc. Med. 23 855 1930

— The Fundamental Principles Involved in the Use of the Bone Graft in Surgery Am. J M Sc. 149 313 1915.

— Injuries and Diseases of the Hip, New York, 1937 Paul B. Hoeber Inc.

Andrews E. W Multiple Drilling of Fractures An Old Fashioned Operation Revised, Surg Clin. Chicago 3 243, 1919

Armstrong J R. Bone-Grafting in the Treatment of Fractures Baltimore 1945 The Williams & Wilkins Co

Barnard L., and Stubbins, S. G Styloidectomy of the Radius in the Surgical Treatment of Non Union of the Carpal Navicular A Preliminary Report, J Bone & Joint Surg. 30-A: 98 1948.

Basom, W C., Breck, L. W and Herz, J R Dual Grafts for Non Union of the Clavicle South. M. J 40 898 1947

Beck A. Zur Behandlung der verzogerten Konsolidation bei Unterschenkelbruchen, Zentralbl. f. Chir 56 2090 1929

Bennett, G E Fractures of the Humerus With Particular Reference to Nonunion and Its Treatment, Ann Surg. 103 991, 1936.

Bishop, W A., Jr., Stauffer R. C. and Swenson, A. L.: Bone Grafts. An End Result Study of the Healing Time, J Bone & Joint Surg 29 961 1947

Blount, W P Blade-Plate Internal Fixation for High Femoral Osteotomies J Bone & Joint Surg. 25 319 1943

Blumenfeld I. Pseudarthrosis of the Long Bones, J Bone & Joint Surg 29 97, 1947

Boyd H. B The Bridging of Bone Defects, Am. Acad. Orthop Surgeons, Lect., Reconstruction Surgery of the Extremities Ann Arbor Mich., 1944, J W Edwards.

Boyd, H B The Treatment of Ununited Fractures, M. Press 213 116 1945

Boyd H. B. The Treatment of Difficult and Unusual Non unions. With Special Reference to the Bridging of Defects, J Bone & Joint Surg. 25 535, 1943.

Boyd H. B., and George I. L. Complications of Fractures of the Neck of the Femur J Bone & Joint Surg 29 13 1947

Boyd H. B and George, I. L. Fractures of the Hip Results Following Treatment. To be published.

Brackett E. G Fractured Neck of Femur, Operation of Transplantation of Femoral Head to Trochanter Boston M & S. J 192 1118 1925

— Reconstruction Operations for Old Ununited Fractures of the Neck of the Femur J Bone & Joint Surg 20 93 1938.

Brackett, E. G: Reconstruction Operations for Old Ununited Fractures of the Neck of the Femur J Bone & Joint Surg 20 93 1938.

Brackett, E. G., and New M. S.: Treatment of Old Ununited Fracture of the Neck of the Femur by Transplantation of the Head of the Femur to the Trochanter Boston Med. & Surg J 177 351, 1917

Brown, J B.: Surface Repair of Compound Injuries, J Bone & Joint Surg 26 448, 1944.

Buchanan, J J: A New Method of Bone Transplantation for Ununited Fractures, Internat. J Surg 25 309 1912.

Burnett, J H: Fractures of the (Navicular) Carpal Scaphoid, New England J Med. 211: 56 1934.

— Further Observations on Treatment of Fracture of the Carpal Scaphoid (Navicular) J Bone & Joint Surg 19 1099 193

Caldwell, G A. Repair of Bony Defects Associated with Osteomyelitis, Ann. Surg. 123 698, 1946

Callahan, J J Cubbins, W R., Scuderi, C. S., and Hamilton, E. Revascularization of the Carpal Bones, Radiology 44 171, 1945

Campbell, W C The Autogenous Bone Graft, J Bone & Joint Surg 21 694 1939

—: Fractures of the Neck of the Femur Ann. Surg 70 600 1919

— The Fate of the Bone Graft: A Clinical Study, South. M J 12 519, 1919
—: Transference of the Fibula as an Adjunct to Free Bone Graft in the Tibial Deficiency J Orthop. Surg 1 62., 1919
— Ununited Fractures of the Neck of the Femur South. M J 13 5.., 19?0
— The Onlay Graft in the Treatment of Ununited Fractures of the Long Bones South M J 20 10., 19?
— The Treatment of Ununited Fractures Am. J Surg 37 1, 1923
—: Ununited Fractures, Arch. Surg 24 990 1932.
— Ununited Fractures of the Shaft of the Humerus Ann. Surg 105 135 193
—: Ununited Fracture of the Neck of the Femur Surgery 1: 409 193.
—: Onlay Bone Graft for Ununited Fractures Arch Surg 38: 313, 1939
— Ununited Fractures of the Neck of the Femur Surg Gynec Ob t 69: 097 1939
Campbell W C., and Boyd, H B: Fixation of Onlay Bone Grafts by Means of Vitallium Screws in the Treatment of Ununited Fractures Am J Surg 51 ?48 1941
Campbell, W C., and Smith Hugh Treatment of Ununited Fractures of the Neck of the Femur Southwestern Med 25 70 1941
Carrell, W B. Transplantation of the Fibula in the Same Leg, J Bone & Joint Surg 20 62. 1938.
Carter Ralph M: A New Treatment for Delayed Union or Nonunion in Fractures, J Bone & Joint Surg. 16 925 1934
Cave E. F: The Carpus with Reference to the Fractured Navicular Bone, Arch. Surg 40 54 1940.
Cobey M. C., and White R. K An Operation for Non Union of Fractures of the Carpal Navicular J Bone & Joint Surg 28 37 1940.
Cole P P: Ununited Fractures of the Mandible Their Incidence Causation, and Treatment Brit. J Surg 6 57 1919
Coleman, H. M., Bateman, J E., Dale, G M., and Starr, D E Cancellous Bone Grafts for Infected Bone Defects Single Stage Procedure Surg., Gynec. & Obst. 83 392 1946.
Colonna, Paul C.: A New Type of Reconstruction Operation for Old Ununited Fracture of the Neck of the Femur J Bone & Joint Surg 17 110 1935
Compere, E. L., and Wallace G Etiology of Aseptic Necrosis of the Head of the Femur After Transcervical Fracture, J Bone & Joint Surg 24 831 1942.
Converse, J M.: Plastic Repair of the Extremities by Non Tubulated Pedical Skin Flaps, J Bone & Joint Surg 30 A 163, 1948
Dickson, F D: Influence of Infection Past or Present on the Selection of Cases Am. Acad. Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944 J W Edwards.
Dickson, J A. The High Geometric Osteotomy with Rotation and Bone Graft, for Ununited Fractures of the Neck of the Femur A Preliminary Report, J Bone & Joint Surg 29 1005 1947
Dickson, J A. Treatment of Ununited Fractures of the Neck of the Femur by Means of Bone Graft and Smith Petersen Nail, S Clin. North America 19 123. 1939
Dickson, J A.: Personal communication, 1948
Elkenbary C. F Transplantation of the Entire Fibula to Replace the Tibia Northwest Med. 27 284 1928.
Ettorre M. Risultati a distanza della cura delle fratture recenti del collo femorale con la osteotomia sottotrocanterica, Troisième Congrès Internat. de Chir Orthop., 1936, p. 571.
Flanagan, J J., and Burem, H. S.: Reconstruction of Defects of the Tibia and Femur with Apposing Massive Grafts from the Affected Bone J Bone & Joint Surg 29 58. 1947
Gaenslen, F J The Schanz Subtrochanteric Osteotomy for Irreducible Dislocation of the Hip J Bone & Joint Surg 17 76 1935
Galland, Walter L: Ununited Fractures of the Neck of the Femur Treatment by the Bifurcation Operation, Am. J Surg 30 410 1935
Gallie, W E., and Le Mesurier A. B. The Late Repair of Fractures of the Patella and of Rupture of the Ligamentum Patellae and Quadriceps Tendon J Bone & Joint Surg. 9 47 1927
Ghormley R. K. Preparation of Patients for Bone Grafting in Cases of Nonunion, Am. Acad. Orthop Surgeons, Lect., Reconstruction Surgery of the Extremities Ann Arbor Mich., 1944 J W Edwards.
Ghormley R. K., and Lipscomb P R. The Use of Untubed Pedicle Grafts in the Repair of Deep Defects of the Foot and Ankle. Technique and Results, J Bone & Joint Surg. 26 483, 1944
Gill, A. B Arthrodesis for Ununited Fracture of the Neck of the Femur J Bone & Joint Surg 21 710 1939
Gill, A. B. Arthrodesis of the Hip for Ununited Fractures, J Bone & Joint Surg 29 305 194?
Gill, A. Bruce Treatment of Ununited Fracture of the Bones of the Forearm Surg Clin. North America 12 1535 1932.

Harkins, H N., and Phemister D B: Simplified Technic of Onlay Grafts, J A M. A. 109 1501 1937

Henderson, M. S: The Treatment of Ununited Fractures of the Tibia by the Transplantation of Bone Ann. Surg 59 486 1914.

—: Nonunion in Fractures: The Massive Bone Graft, J A. M. A. 81: 463, 1923.

Henderson M. S Massive Bone Graft Applied for Nonunion of the Humerus, Surg., Gynec. & Obst. 46 397 1928.

— The Massive Bone Graft in Ununited Fractures, J A. M. A 107 1104 1936.

Henderson, M S. Present Day Treatment of Ununited Fractures of the Neck of the Femur Minnesota Med 23 359 1940

Henderson M. S.: Bone Graft in Ununited Fractures, J Bone & Joint Surg 20 635 1938

Henderson, M. S. Ununited Fracture of the Neck of the Femur Treated by the Aid of a Bone Graft, J Bone & Joint Surg 22 97, 1940

Henderson M. S. Treatment of Nonunion in Fractures Am. Acad. Orthop. Surgeons, Lect, Reconstruction Surgery of the Extremities Ann Arbor Michigan, 1944 J W Edwards.

Henderson, M S. Treatment of Ununited Fractures of the Hip S. Clin. North America 24 751, 1944

Henderson, M. S., Noble, T P., and Sandiford K. Ununited Fractures With Special Reference to the Chemistry of the Blood J Bone & Joint Surg. 8 607 1926.

Hermann, O J: The McMurray Osteotomy for Nonunited Hip Fractures, New England J Med. 232 186, 1945

Hermann, O J: Reconstructions in Nonunited Femoral Neck Fractures, Surg., Gynec. & Obst. 70 403 1940

Hermann, O J Ununited Hip Fractures, New England J Med. 226 601 1942.

Hoglund Emil J New Method of Applying Autogenous Intramedullary Bone Transplants and of Making Autogenous Bone Screws, Surg Gynec. Obst. 24 243 1917

Huntington T W Case of Bone Transference Ann. Surg 41 249 1905

Irwin, J C., and Ghormley R. K. Brackett Operation for Ununited Fracture of the Neck of the Femur Surgery 22 819 1947

Jahss, S A., and Mintz, B. J Transverse Osteotomy in Ununited Fractures of the Femoral Neck, Bull. Hosp. Joint Dis. 2 143 1941

Jones, Ellis Trochanteric Transplantation in the Treatment of Fractures of the Neck of the Femur J Bone & Joint Surg 14 250 1932.

Kelly R. P., Rosati, L. M., and Murray R. A. Traumatic Osteomyelitis; The Use of Skin Grafts Technic and Results, Ann. Surg. 122 1 1945

Kelly R. P., Rosati L. M., and Murray, R. A. Traumatic Osteomyelitis The Use of Skin Grafts, Subsequent Treatment Ann. Surg 123 988, 1946

Key J Albert Treatment of Nonunion of Fractures, Surgery 1 730 1937

Knight, M. P and Wood, G O Surgical Obliteration of Bone Cavities Following Traumatic Osteomyelitis, J Bone & Joint Surg 27 547 1945

Krida, A. The Whitman Reconstruction Operation for Complications of Fracture of the Neck of the Femur J Bone & Joint Surg 29 310 1947

Leadbetter G W Cervical Axial Osteotomy of the Femur A Preliminary Report J Bone & Joint Surg 26 713, 1944

Littler J W Metacarpal Reconstruction, J Bone & Joint Surg 29 7[illegible]3, 1947

Lorenz, Adolf: Ueber die Behandlung der irreponiblen angeborenen Hüftluxationen und der Schenkelhalspseudarthrosen mittels Gabelung (Bifurkation des oberen Femurendes) Wien. klin. Wchnschr 32 997 1919

Luck, Vernon J Reconstruction Operation for Pseudoarthrosis and Resorption of Neck of Femur J Iowa M Soc. 28 620 1938.

Magnuson, P B The Repair of Ununited Fracture of the Neck of the Femur J A. M. A. 98 1791 1932.

Magnuson, P B Report of 59 Consecutive Cases of Ununited Fracture of the Neck of the Femur Surgery 7 763 1940

Matti Hermann Technic and Results of My Operation for Pseudoarthrosis, Zentralbl. f Chir 63 1442 1936, J Bone & Joint Surg 19 870 1937

McKeever F M., and Buck, R M Fracture of the Olecranon Process of the Ulna, Treatment by Excision of Fragment and Repair of Triceps Tendon, J A. M. A. 135 1, 1947

McMurray, T P Ununited Fractures of the Neck of the Femur J Bone & Joint Surg 18 319 1936.

— Fracture of the Neck of the Femur Treated by Oblique Osteotomy Brit. M. J 1 330 1938

Miller O L. Massive Bone Graft Report of Cases, South. M. J 25 211, 1932.

Miller R. C, and Phalen, G S. The Repair of Defects of the Radius with Fibular Bone Grafts, J Bone & Joint Surg 29 629 1947

Moore, J R. Bridging of Bone Defects in Compound Wounds, J Bone & Joint Surg. 26 456 1944.

orris, H D: Tenon and Mortise Grafts for Bridging Metacarpal Defects Due to Gunshot Wounds Surgery 20 361 1916.
urray C. R.: Delayed and Nonunion in Fractures in the Adult, Ann. Surg 93 961, 1931
urray Gordon: Bone-Graft for Non Union of the Carpal Scaphoid, Brit. J Surg 22 63, 1934
—: Bone Graft for Non Union of the Carpal Scaphoid Surg Gynec & Obst. 60 540 193.
urray, G End Result for Bone-Grafting for Non Union of the Carpal Navicular, J Bone & Joint Surg. 28 749, 1940.
utter J A On Delayed Union and Non Union of Fractures, J Bone & Joint Surg 20 104 1922.
rell, Svante: Surgical Bone Grafting With "Os Purum," "Os Novum," and "Boiled Bone" J Bone & Joint Surg 19: 873 1937
smond-Clarke H. Fractures of the Carpal Scaphoid, Paper Read Before The American Academy of Orthopedic Surgeons, 1948
hemister D B. Treatment of Ununited Fractures by Onlay Bone Grafts Without Screw or Tie Fixation and Without Breaking Down of the Fibrous Union, J Bone & Joint Surg 29 946 1947
hemister, D B. Splint Grafts in the Treatment of Delayed and Non Union of Fractures Surg Gynec. Obst 52 376 1931
utti V L osteotomie intertrochanterienne dans le traitement des pseudarthroses du col du femur Presse méd 45 1611 193
eich, R. S.: Ununited Fracture of the Neck of the Femur Treated by High Oblique Osteotomy J Bone & Joint Surg 23 141 1941
iedel, Gustav: Halteloschplatte für Schanz sche Schrauben Zentralbl. f Chir 57 84 1930
oyle N D The Treatment of Ununited Fractures, M J Australia 1 409 1934
owe, M L., and Ghormley R K Brackett Operations for Ununited Fractures of the Neck of the Femur J Bone & Joint Surg. 26 249 1944
yerson, Edwin W The Treatment of Ununited Fractures, Milwaukee Proc. Inter-State Post-Grad. Med. Assem. N A., 1931 p. 413.
—: Ununited Fractures, South. M J 29 512, 1936.
antos, J V: Changes in the Head of the Femur After Complete Intracapsular Fracture of the Neck, Arch. Surg 21 470, 1930
caglietti, Oscar: Il perone in posto della tibia. Boll e mem, Soc. Emiliano-Romagnola di Chir 2 No. 2, 1936
chanz, A. Ueber die nach Schenkelhalsbrüchen zurückbleibenden Gehstörungen, Deutsche med. Wchnschr 51 730 1925
elmek, Fritz Die Behandlung der verzogerten Callusbildung des Os naviculare manus mit der Beck schen Borung Zentralbl. f Chir., 57 2600 1930
—: Die Verletzungen der Handwurzel, Ergebn. d. Chir u. Orthop. 23 1 1930
chumm, Herman C.: The Schanz Osteotomy for Fractures of the Neck of the Femur J Bone & Joint Surg. 19 955 1937
ever J W Nonunion in Fracture of the Shaft of the Humerus J A M A. 104 382, 1935
Shaw D T., and Payne R. L. Repair of Surface Defects of the Upper Extremity Ann. Surg 123 705, 1946.
herman, M S., and Phemister D B. The Pathology of Ununited Fractures of the Neck of the Femur J Bone & Joint Surg 29 19 194,
Smith Petersen, M N., Larson, C. B., Aufranc, O E. and Law W A: Complications of Old Fractures of the Neck of the Femur Results of Treatment by Vitallium Mould Arthroplasty J Bone & Joint Surg 29 41, 1947
Soto-Hall, Ralph Recent Fractures of the Carpal Scaphoid J A. M. A. 129 335 1945.
Soto-Hall Ralph Personal communication 1948.
Soto-Hall, R., and Haldeman, K O The Conservative and Operative Treatment of Fractures of the Carpal Scaphold (Navicular) J Bone & Joint Surg 23 841 1941.
Soto-Hall, Ralph, and Haldeman, K. O: Treatment of Fractures of the Carpal Scaphoid J Bone & Joint Surg 16 822, 1934
Speed, K. Subtrochanteric Osteotomy for Ununited Fractures of the Neck of the Femur Ann. Surg 124 576, 1946.
Speed, J S. Reconstruction Operation on the Hip J A M. A 87: 1031 1926.
—: Bone Grafts in Ununited Fractures, South. M J 23: 1 9 1930
Speed J S., and Smith, Hugh: Trochanteric Osteotomy for Ununited Fractures of the Neck of the Femur South. M. J 34 798, 1941.
Speed Kellogg: Fractures of the Carpus, J Bone & Joint Surg 17 965, 1935
—: Blood Serum Calcium in Relation to the Healing of Fractures, J Bone & Joint Surg 13 58, 1931.
Steindler A.: Fracture Disabilities of the Wrist, Surg Gynec. Obst. 58 487 1934
Stone, J S.: Partial Loss of the Tibia Replaced by Transfer of Fibula, Ann. Surg 46 628, 1907
Stuck W G., and Hinchey J J Experimentally Increased Blood Supply to the Head and Neck of the Femur, Surg., Gynec. & Obst. 78: 160 1944.

Thibodeau, A. The Bridging of Defects by Autogenous Grafts and Bone Chips, Am. Acad. Orthop. Surgeons, Lect., Reconstruction Surgery of the Extremities, Ann Arbor Michigan, 1944 J W Edwards.
Thornton, Lawson: Old Dislocations of Os Magnum—Open Reduction and Stabilization, South M. J 17 430 1924.
Wagner J Huber Personal communication.
Watson-Jones, R. Reconstruction of the Forearm After Loss of the Radius, Brit. J Surg 22 23, 1934-35
West, W K. Choice of Bone Grafts in Fracture Surgery, South. M. J 30: 685 1937
Whitman, Armitage End Results of Reconstruction Operation for Ununited Fracture of Neck of the Femur J A. M. A. 77 918, 1921
Whitman, Royal Reconstruction Operation for Ununited Fracture of the Neck of the Femur, Surg Gynec. Obst. 32 479 1921
—: Operative Treatment of Ununited Fracture of the Neck of the Femur Surg. Gynec. Obst. 50 885, 1930
Wilson, P D Trochanteric Arthroplasty in the Treatment of Ununited Fractures of the Neck of the Femur J Bone & Joint Surg 29 313, 1947

CHAPTER XI

PERIPHERAL NERVE INJURIES

By

Francis Murphey, M D

During World War I, injuries of the peripheral nerves for a time received wide attention Following the war, however interest in the subject was quickly lost and critical follow up studies largely were abandoned Consequently, little information was gained and, until World War II, peripheral nerve surgery was generally neglected and of poor quality The vast number of peripheral nerve injuries sustained by military personnel during World War II however, renewed interest in this field A wealth of material has been accumulated, and analyses of these cases may provide answers to some fundamental problems among them the following (1) What may one reasonably expect as to return of motor sensory, and autonomic function after suture of each major peripheral nerve? (2) What is the effect of associated vascular bony and soft tissue damage? (3) What is the effect of extensive mobilization with or without transplantation of a nerve? (4) How long may neurorrhaphy be delayed? (5) What is the effect of nerve stretching before, at the time of and after suture? (6) What is the effect of tension on the suture line? (7) What is the best suture material? (8) What is the effect of tension sutures? (9) What is the effect of the use of cuffs?

Diagnosis of peripheral nerve injuries according to most textbooks is far too complicated for the understanding of any but the most experienced neurologist Adherence to the time honored analysis of movement ' as a method of determining paralysis of various muscles, and attempts to memorize various types of deformities, complete details of the sensory innervation of each nerve, and complicated electrical formulas have served not only to confuse, but also to discourage thoroughly the most enthusiastic student Further far too little emphasis has been placed upon the technical details of the surgery and postoperative care. Most standard works afford little information regarding the details of nerve exposure exact methods of overcoming large gaps between nerve ends, postoperative immobilization and other practical problems

In the subsequent section, the diagnosis and treatment of peripheral nerve injuries will be described as simply and practically as possible This discussion is based largely upon observations of 3,276 major peripheral nerve injuries in 2,849 patients, casualties of World War II The author acknowledges the assistance of Dr John W Kirklin and other members of the neurosurgical service at O'Reilly General Hospital in the accumulation of this information.

For details of embryology microscopic anatomy physiology, and the regeneration of peripheral nerves, the reader is referred to other works The majority of operations for irreparable nerve lesions is described in Chapter XXII A few tendon transference procedures which are particularly applicable to peripheral nerve lesions will be described in this section.

Effects of Peripheral Nerve Injuries

Motor—When a peripheral nerve is severed at a given point, all motor function of the nerve below that point is abolished. All muscles supplied by branches of the nerve given off below the level of the lesion are paralyzed and rapidly atrophy Fibrosis develops most rapidly in the smaller muscles, such as the intrinsic muscles of the hands and feet. The muscles affected are fairly constant. Anomalous innervation of various muscles, however particularly those in the hand, may confuse the most expert examiner This cannot be determined by muscle examination alone, one must resort to stimulation of the nerve in situ nerve block or actual exploration of the nerve to establish this fact

Substitution and trick movements also present some difficulty For example, opposition of the thumb can be accomplished by many patients, even though the nerve supply to the opponens pollicis is completely severed Also the wrist may be partially extended in the presence of a complete radial nerve paralysis, by simple flexion of the fingers *Errors which result from trick movements may be avoided if one tests only those muscles whose tendons or bellies or both can be seen or palpated*

Sensory—Sensory loss generally follows a definite anatomic pattern though the factor of overlap from adjacent nerves may confuse the uninitiated. After severance of a peripheral nerve, only a small area of complete sensory loss is found This represents the area supplied exclusively by the severed nerve and is called the autonomous zone, or isolated zone of supply of that nerve. There is a larger area, corresponding to the gross anatomic distribution of the nerve wherein sensitivity is reduced and can be determined by ordinary methods of examination this is known as the intermediate zone. When the nerve is left intact and the adjacent nerves are blocked out, there is an area of sensibility which exceeds the gross anatomic distribution of the nerve this is known as the maximal zone

It has long been recognized that the intermediate zone becomes smaller as the time passes when actual regeneration is known to be possible. The cause of this is not known though Livingston believes it to be due to ingrowth of adjacent nerves. Needless to say, shrinkage of the intermediate zone suggests regeneration to the inexperienced surgeon and is responsible for as many delayed explorations as trick movements. One need only know the minimum autonomous zone of each nerve to avoid such errors.

Reflex.—Complete severance of a peripheral nerve abolishes all reflex activity This is true of severance of either the afferent or efferent arc. Frequently however reflex activity is abolished in partial nerve injuries when neither arc is completely interrupted and it is thus not a reliable guide to the severity of the injury

Autonomic.—Interruption of a peripheral nerve is followed by abolition of sweating in its field of distribution. The area affected usually corresponds to but may be slightly larger than the sensory deficit, and is easily outlined by either the starch iodine test or instruments for determining skin resistance (Richter dermometer) If the injury is incomplete and especially if associated with causalgia, sweating may be excessive and may involve areas beyond the intermediate zone of the nerve.

ities of sensation should be tested and abnormalities mapped out, analgesia to pin prick in the autonomous zone is usually sufficient to indicate a complete sensory loss. If pain to pin prick is present in this zone it may be definitely stated that the nerve is not completely severed. Pain from deep pressure (for example, by squeezing the tip of the index finger) is often found when the nerve is completely severed and is therefore of little diagnostic value. It is significant only if no pain is elicited. The starch iodine test and measurement of the skin resistance are both satisfactory methods of determining loss or reduction in sweating. This area usually corresponds to the sensory loss. It is usually of confirmatory value only but may assume more importance in recognizing functional disturbances. Lesions of the nerve root proximal to the point of junction with sympathetic fibers will not show any disturbance of sweating.

The Tinel sign is the tingling in the area of distribution of the affected nerve, induced by gentle percussion over the nerve distal to the level of the injury. It may be indicative of regenerating nerve fibers which have not yet obtained their myelin sheath or evidence of incomplete division of the nerve. In general, however, it may be said that if the Tinel sign is present, there are at least a few regenerating or intact nerve fibers below the level of the lesion. If the sign cannot be elicited within two months after the injury the lesion may be regarded as complete, provided, of course, motor and sensory loss are complete. The sign is most useful in charting the progress of the regenerating axones. Percussion along the course of a nerve to the point of most pronounced tingling may also be of value in localizing the lesion in multiple wounds.

Electrical stimulation through the intact skin is often more confusing than helpful. Faradic stimulation is at times of little value because many normally innervated muscles fail to respond to this current. On the other hand, if response to Faradic stimulation is still present after three weeks, the muscles which respond are usually capable of voluntary contraction and one may thus conclude that the lesion is not complete. Further, if response to galvanic stimulation is fairly normal after three weeks, function will return spontaneously. Neither of these tests is reliable, however, since a completely severed nerve may respond in a manner which indicates only partial severance and a slightly injured nerve may respond not at all.

Direct stimulation of the nerves in situ, though still in the stage of investigation, has proved satisfactory in the author's hands, in a small series of cases. This is accomplished by the simple procedure of introducing two ordinary hypodermic needles through the skin to a point near the nerve, and connecting these needles to two 1½ volt dry cell batteries with a polarity reversal switch. This test is of value only after Wallerian degeneration has progressed to the point where conductivity of the distal portion of the nerve has been abolished—usually two to four days after the injury.

General Considerations of Treatment

Indications for Operation.—If a peripheral nerve is known to be severed, neurorrhaphy is of course indicated. If the condition of the nerve is not known, and examination reveals a complete, physiologic lesion, exploration is

likewise indicated One is justified in delaying operation an appreciable length of time, only if *progressive improvement in both sensation and power is manifested*

Time of Operation —It has been the time-honored policy to advise primary suture when possible. This is logical when one considers what happens, not only to the distal end of the nerve but to the motor end plates, sensory nerve endings, muscles, joints, and other tissues of the denervated extremity It has never been proved however that such a lesion is a *surgical emergency* and that delay of two or three weeks *compromises an optimum result* In fact it is probable that, if one has a choice a delay of two or three weeks is advisable, with the possible exception of those lesions which are produced by clean cuts with a knife In regard to war wounds, Seddon has stated "The delayed operation converts the suture from a procedure carried out under restriction into one in which the surgeon is free to do as he wishes. At Oxford (England) all the primary sutures compare unfavorably with early secondary suture and if I had the misfortune to suffer a nerve injury myself I would prefer the secondary operation.' There are two reasons for this. First immediately after the injury other than by a knife or other very sharp instruments, one cannot determine the extent of damage to the nerve proximal and distal to the site of the injury Thus, it is not possible to determine the amount of the nerve ends which must be sacrificed Second, the Schwann cells which grow out from the distal ends to meet the regenerating axones from the proximal ends do not attain maximum activity for some time In addition as Spurling and Woodhall have pointed out, (1) primary suture at the time of débridement is not feasible by any technical standards, nor is it compatible with the surgical principles of preservation of *life or extremity* (2) *mobilization and transplantation procedures essential* for overcoming nerve gaps and obviating suture line tension are surgically unsound because of danger of infection and (3) the epineurium of a freshly divided nerve is thin and friable and lacks the tensile strength to hold sutures.

Regardless of one's opinion concerning the advisability *of primary* or secondary suture, one thing must be made clear Delay of *operation* in expectation of possible spontaneous regeneration is inexcusable. *There* are *few* exceptions to this rule. Only *if the patient's life or limb is* seriously endangered should the operation be postponed. A fractured *bone* is not a contraindication to operation In fact, operation before the fracture *is united is* definitely advantageous for two *reasons* (1) *If* bone shortening is necessary resection of an ununited or partially united fracture is a much less *formidable* procedure than resection of a fully united bone. (2) *Restriction of joint* motion is minimal if the nerve is repaired soon after the injury whereas later motion will be materially limited, perhaps preventing flexion *of* the joint to a degree necessary to overcome gaps between the nerve ends.

In a *series of* 957 neurorrhaphies of major peripheral nerves, Kirklin and Murphey *have found that other factors* being equal, function is better when secondary suture is not too long delayed. Reasonably satisfactory motor function may be obtained, *however after suture is delayed as* long *as six months*, and an interval of *nine months* is not an insurmountable barrier to good function. In a few cases, some *degree of* motor function returned after a delay of fifteen *months*. It was *observed that* the interval between the severance of the

nerve and the suture had more bearing upon sensory return Although sensory return is never perfect, discriminative sensation returned in a considerable number of nerves sutured within three months, but returned with rapidly decreasing frequency after this period and rarely after nine months. Sensory return in the median and ulnar nerves was fair but disappointing in the sciatic, peroneal, and posterior tibial nerves. Thus, it is apparent that early suture is even more essential in nerves with large or important sensory components, such as the median nerve and the tibial component of the sciatic, than those with a large motor function, such as the radial.

Instruments and Equipment.—Operation on peripheral nerves should never be undertaken without some type of stimulator such as a simple inductorium with an output of 0 to 5 volts. It is indispensable in the investigation of partially severed nerves, neuromas in continuity and in locating and thus enabling one to preserve branches given off above or at the lesion which are *still functioning but are encased in scar tissue* *Instruments for handling* and dissecting delicate tissues are always essential. Suction apparatus and an electrosurgical unit facilitate the procedure Gel foam and thrombin are useful for controlling the bleeding from the cut ends of the nerve Fine waxed silk (6-0) or tantalum (.003) on small atraumatic needles are probably equally satisfactory for suture material. Although there is no doubt that silk causes more tissue reaction than tantalum the latter is much more difficult to use is practically invisible and cuts through tissue more readily than silk. These disadvantages probably balance each other There is no reason to believe that tantalum interferes with the anastomosis. Tantalum however is opaque in the roentgenogram and thus permits one to determine postoperatively by repeated roentgenograms, whether the suture line is intact If tantalum is not used in the anastomosis it is always wise to insert two tantalum marker sutures one in the epineurium of both the proximal and distal ends of the nerves.

Preparation and Draping—Since the proper length of an incision can seldom be determined in advance, it is mandatory that the entire extremity be prepared (*Chapter III*) *For operations on the upper extremity*, the axilla, shoulder neck, and chest should be included in the field of preparation and for those on the lower extremity the buttocks and low back.

After preparation of the field, the proposed incision is marked on the extremity and cross hatched with a knife before the land marks are covered. The extremity is then encased in sterile stockinet. If it is desirable to watch the movements of the muscles in the hand when the nerve is stimulated, the hand should be encased in a large rubber glove instead of stockinet.

SURGICAL TECHNIC

In no type of surgery is the incision more important. Every incision should extend well above and below the lesion and, when possible, should follow the course of the nerve, though no incision should cross a joint at a right angle, and the flexor creases of the skin should be avoided Curvilinear incisions are better than straight ones. Short incisions are, no doubt the cause of more futile nerve operations than any other single factor except the surgeon's in

experience As an example if necessary one should never hesitate to extend an incision from the axilla to the wrist in order to overcome a large defect in the ulnar or median nerve

It is axiomatic that the injured nerve should be exposed first above and then below the lesion before approaching the site of the injury The nerve should then be stimulated above and below the lesion and the response recorded In the dissection of the nerve from scar tissue it should be repeatedly stimulated in order to locate any branches which might still be functioning Before the nerve ends are mobilized, orientation sutures of black silk are placed in the epineurium of the proximal and distal ends so that neurorrhaphy if necessary may be accomplished without undue rotation of the ends.

Handling of the nerve during mobilization may be facilitated by the use of moist tapes or pieces of rubber tissue. The portion of the nerve not being operated upon at the moment should be covered with moist sponges

If the nerve has not been completely severed or a neuroma in continuity is present it is often difficult to determine whether a neurolysis, partial neuror rhaphy or neurorrhaphy will afford the best prospect of a good result. The surgeon may need to use all the experience at his command to arrive at the correct solution Stimulation above the injury for motor response below is a sine qua non If a local anesthetic is used stimulation below the lesion will give some idea of whether a significant number of sensory fibers have escaped injury or regenerated. Examination of the site of injury may assist one in determining what course to pursue The neuroma may be injected with saline, and if the solution passes up and down the nerve trunk with little difficulty, the neuroma should probably be left alone This, however can be misleading and unless the response to stimulation is positive, i e., good motor or sensory response endoneural neurolysis is advisable.

Endoneural Neurolysis

When an endoneural neurolysis is undertaken, it should be borne in mind that a partial or complete neurorrhaphy may be necessary and one should pre serve intact as much of the epineurium and normal nerve as possible

The epineurium is incised longitudinally above the lesion, beginning not more than one-half centimeter above the level of the gross changes in the nerve as determined by palpation The incision should not be extended above this point, since the epineurium may become frayed and, in the event a complete neurorrhaphy is necessary an additional amount of nerve will not have to be sacrificed For the same reason the lower end of the incision should be similarly limited The flaps of epineurium are retracted laterally by small hemostats and undermined widely With a bayonet pointed knife, the funiculi are sepa rated, if possible, by both sharp and blunt dissection. If a fair number of intact funiculi can be traced through the neuroma, it should be left alone On the other hand, if stimulation fails to elicit a response and few if any, intact funiculi can be found, neurorrhaphy is indicated. After all this has been done if one is still in doubt resection of the neuroma is best delayed about six weeks, in the hope of recovery If necessary, a resection and neurorrhaphy may then be performed Another alternative is partial neurorrhaphy

Partial Neurorrhaphy

Partial severance, particularly of the larger nerves, as the sciatic, and cords and trunks of the brachial plexus, is not uncommon. In such injuries of these nerves, partial neurorrhaphies are most often performed and can be accomplished fairly satisfactorily. At best, however, a partial neurorrhaphy is never quite as satisfactory from a purely technical point of view as a complete one, and often in the smaller nerves is impracticable.

The decision to perform a partial neurorrhaphy is likewise often difficult and made only after the most careful investigation of the lesion. If one half of the nerve (particularly a larger nerve) is disrupted, a partial neurorrhaphy is advisable. However if a good motor response to stimulation has been obtained, it would obviously be unwise in some nerves, such as the ulnar nerve, to risk injury of good motor funiculi to attempt restoration of sensation in the little finger.

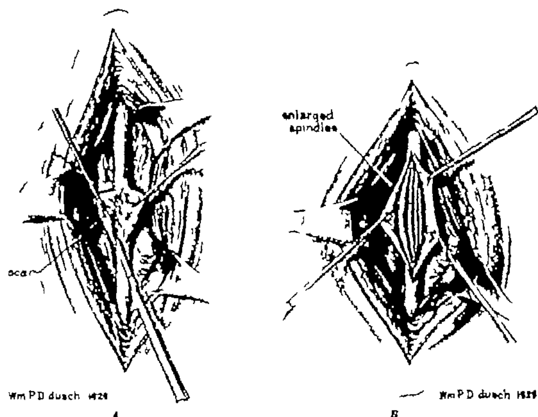


Fig. 424.—Neurolysis and endoneurolysis. A, Scar tissue dissected from nerve until epineurium is exposed. B, If scar tissue is endoneural, epineurium is opened and funiculi are freed from scar tissue. (From Dean Lewis' Practice of Surgery. Hagerstown, Md., 1923, W. F. Prior Co.)

On the other hand if a large majority of funiculi in smaller nerves is severed and one cannot demonstrate important function in the few remaining by stimulation, a complete neurorrhaphy is probably better. Suture of a few funiculi is usually impracticable here; plasma clot suture may be of real value.

Once one is committed to a partial neurorrhaphy it is then permissible to extend the incision longitudinally in the epineurium proximally and distally several centimeters beyond the lesion. The intact funiculi are then dissected out for a similar distance. The ends of the injured portion are resected back

to good funiculi and the longitudinal incision in the epineurium is closed with No 6-0 silk after the intact funiculi have been excluded The injured portion is thus again enclosed in epineurium except at the cut ends and an end to-end anastomosis is accomplished, as in a complete neurorrhaphy In some cases, reconstruction of the epineurium so that it completely surrounds the severed portion is impossible. In this event, the sutures must be placed through endoneural connective tissue which is unsatisfactory at best Such a procedure leaves the intact part of the nerve in a loop Needless to say the endoneural dissection should be long enough to prevent this portion from sharply kinking "

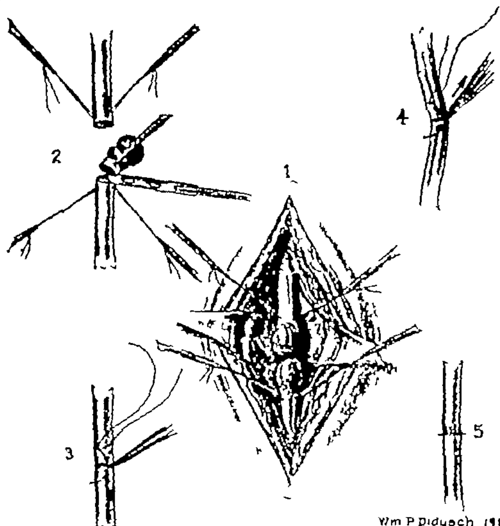


Fig 527—Neurorrhaphy 1 Divided nerve exposed. 2 Sutures are inserted on each side to prevent rotation, and to be used for traction. Successive pieces of bulbous end of proximal and distal segments removed to normal funiculi. Sutures of fine silk are passed through epineurium. 3, Ends of funiculi should not be retracted. Long sutures inserted, that nerve may be rotated to permit suture posteriorly 4, Epineurium must be closed otherwise, regenerating nerve fibers will pass into surrounding tissues and produce a dense scar about nerve. 5 Suture completed. If silk techni is used throughout, two tantalum marker sutures enable one to determine disruption of suture line by roentgenograms. (From Dean Lewis' Practice of Surgery Hagerstown, Md., 1939 W F Prior Co.)

Neurorrhaphy

When the nerve is completely severed, the only surgical recourse is resection of the neuroma and glioma to normal tissue and an end to-end anastomosis. Before resection of the ends, however one should determine the extent of the gap to be overcome, and then proceed to overcome the gap This is where experience and persistence count the most.

Nerve Crossing—Nerve crossing operations in the extremities are practically never wise nor possible. Rarely, in the presence of a combined median and ulnar lesion of such magnitude that the gap cannot be overcome in either nerve, the ulnar nerve may be sectioned again in the upper arm a length of nerve sufficient to bridge the gap being left between the two ends of the median. The proximal end of the median is then sutured to the proximal end of the free segment of the ulnar nerve. At a second operation six weeks later the distal end of the free segment of the ulnar nerve is sutured to the distal end of the median

Technic of Neurorrhaphy

After one is sure the gap has been overcome, the nerve ends are placed on a sterile wooden tongue blade and the neuroma and glioma are sectioned serially with a razor blade until normal funiculi are observed Even though one uses a hand lens, one occasionally finds nerve ends which appear and feel normal, yet actually contain considerable neuroma, glioma, or scar tissue. To determine whether the ends are satisfactory microscopic sections of the mirror images of the ends sewed together should always be made If the distal end contains any glioma, or if more than one-third of the proximal end consists of neuroma, resection of additional nerve ends at the second operation is mandatory (Kirklin and Murphey) Bleeding from the nerve ends should be controlled with moist cotton pledgets or Gel foam though this is probably not as important as was once believed.

During the process of suture, the extremity is immobilized in an optimum position by an assistant. The orientation sutures are brought into line and the first suture of silk or tantalum is passed through the epineurium of the proximal and distal segments, 1 mm. from the ends and in line with the orientation sutures Other sutures are similarly placed at the opposite, medial, and lateral sides of the nerve If the nerve is to be brought together without tension, these four sutures may be tied, additional intermediate sutures are then placed, to close the epineurium completely If the nerve is brought together under tension, all sutures should be placed, then pulled simultaneously to bring the ends together Thereafter the sutures are tied one by one. Using this technic, a tension suture is rarely necessary

If tantalum has been used, no marker sutures are necessary If not, one metal marker suture should be placed in the epineurium at a given distance above and below the suture line that one may determine by postoperative roentgenograms whether or not the suture line is intact Closure, as will be seen later may at times be quite difficult because of the position of the extremity It is wise in such cases to close most of the wound except at the actual site of the neurorrhaphy before end to-end suture is carried out.

After Treatment.—The extremity is immobilized in plaster splints or casts. As a rule, posterior molded plaster splints are satisfactory for the arm unless the shoulder or the shoulder girdle must be immobilized in the latter event, a Velpeau dressing reinforced with plaster bandage is essential. Following neurorrhaphy in the leg full hip spica casts are mandatory The use of long *leg casts frequently results in separation of the suture line and, for this reason,* are unsuitable.

The wound should not be dressed until the seventh to the tenth day, when the sutures are removed. In removal of the splints or casts, one should be extremely careful to avoid tension on the suture line.

There is considerable divergence of opinion as to when extension of the joints may safely be begun Preferably, in the upper extremity, plaster splints are retained for four weeks, then replaced with metal splints which can be gradually straightened. Straightening of the extremity should cover a period of two or three weeks.

In lower extremities, especially when the peroneal nerve has been sutured it is well to keep the patient in the spica for a minimum of six weeks, then apply a long leg brace with controlled extension of the knee One should allow four weeks or more, depending on the tension on the suture line, for complete extension of the knee Roentgenograms of the suture line should be made at monthly intervals for the first three months to determine the integrity of the suture line. Physical therapy is essential to recovery of function of the extremity

SCIATIC NERVE

The sciatic nerve is composed of fibers from L4 and 5 and S1, 2 and 3 Injuries of this nerve usually are produced by gunshot wounds to the thigh or buttocks. Less often this nerve is injured by posterior dislocations or fracture-dislocations of the hip in the latter type of injury, however the peroneal half of the nerve is injured far more often than the whole nerve. The semimembranous and semitendinous muscles are seldom paralyzed, in even the highest sciatic lesions, though the biceps femoris muscle is not infrequently paralyzed from complete division of the upper one-third of the sciatic nerve as a result of a gunshot wound, and rarely from dislocation of the hip

Examination.—The hamstrings (tibial component of sciatic nerve), the gastrocnemius group (tibial nerve), tibialis anticus and long extensors of toes (deep peroneal nerve), peroneus longus and brevis (superficial peroneal nerve) posterior tibial and long flexors of toes (posterior tibial nerve) are the muscles supplied by the sciatic nerve which may be accurately tested. In this author s experience accurate testing of the intrinsic muscles of the foot is impractical. Stimulation of the sciatic nerve in situ may be of value, though the author has had no real experience with this test, nor has any been reported in the literature

The autonomous zone of the sciatic nerve includes the area over the heads of the metatarsals, over the heel, the lateral and posterior aspects of the sole of the foot, and the dorsum of the foot as far medially as the second metatarsal as well as a narrow strip up the lateral aspect of the leg The autonomous zones of the branches of the sciatic, namely the posterior tibial (lateral and medial plantor), the common peroneal (superficial and deep peroneal) and the sural, are far smaller in proportion, and will be described later

As in other nerves, the skin resistance test or starch iodine test is confirmatory

In multiple wounds, percussion along the course of the nerve to the point of most pronounced tingling is a fairly accurate method of localizing the injury In addition, an exact knowledge of the point of emergence of the various nerve

branches is of benefit if one goes by the latter, however one is more liable to err than by percussion since a branch may be injured after it comes off the nerve

Approach.—The sciatic nerve may easily be exposed from its emergence from the sciatic notch to the point of its division into the tibial and peroneal nerves in the popliteal fossa For injuries near the sciatic notch, the incision

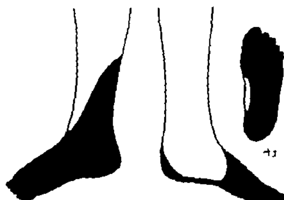


Fig. 528—Autonomous zone of sciatic nerve.

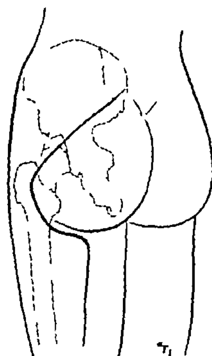


Fig. 529—Line of skin incision for approach to upper portion of sciatic nerve extends from posterior superior iliac spine to trochanter and thence is curved distally along posterior surface of thigh.

is begun at the posterior superior iliac spine and carried diagonally downward and laterally in the direction of the fibers of the gluteus *maximus*, to a point about one inch medial to the greater trochanter of the femur Thence, it is curved medially beneath the gluteal fold to its midpoint, and finally downward along the posterior aspect of the thigh in the usual curvilinear fashion, to a point 10 cm above the skin folds of the popliteal fossa The upper part of the incision is carried through the gluteal fascia and the fibers of the gluteus maxi

mus are separated out to the trochanter It is then wise to incise the fascia of the thigh vertically to the gluteal fold and detach the insertion of the lower fibers of the gluteus maximus from the iliotibial band Thereafter the muscle, with its nerve and blood supply may be reflected medially exposing the nerve up to the pyriformis muscle The latter structure is sacrificed to expose the nerve as it emerges from the sciatic notch If better exposure of the nerve within the sciatic notch is necessary a portion of the sacrum may be removed by a rongeur

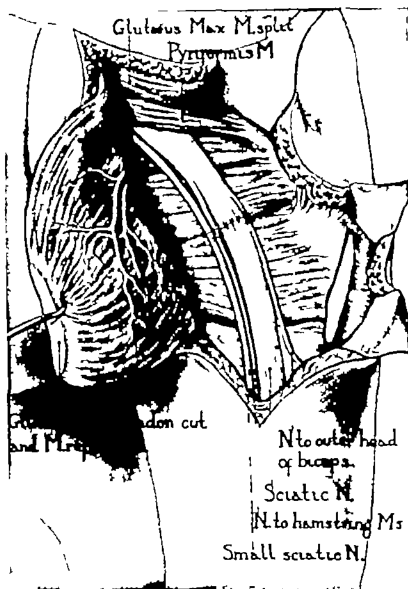


Fig. 530.—Sciatic nerve exposed by separation of fibers of gluteus maximus and division of lower insertion of muscle. Muscle retracted medially together with large gluteal vessels. Suture of nerve and branches. (From Stookey Byron Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

If the injury is somewhat lower the incision over the buttocks may likewise be placed lower If the injury is in the thigh the incision is begun at the gluteal fold and continued downward to a point 10 cm above the knee The fascia is opened vertically along the posterior aspect in line with the skin incision The posterior cutaneous nerve which is just below the deep fascia should be protected In the upper thigh the biceps femoris muscle is identi

fied and retracted medially and the sciatic nerve is identified in the depths of the wound. Distally the nerve is traced beneath the biceps to its point of bifurcation. For additional exposure (Mayfield) the end of the incision is curved to the lateral aspect of the knee if the peroneal is injured, the incision passes down along its course as the nerve crosses the head of the fibula or if the tibial nerve is injured, medially and thence a few centimeters down the medial aspect of the leg These incisions have two material advantages they do not cross the skin folds of the popliteal fossa consequently, contractures and ulcerating scars do not develop Further closure is easily accomplished with the knee flexed.

Methods of Overcoming Defects.—The usual use of extensive mobilization of the nerve including its divisions, flexion of the knee and hyperextension of the thigh will allow one to overcome a gap of as much as 15 cm In the presence of a fractured femur and division of the sciatic nerve, it is highly important, even in the face of draining sinuses, that one operate upon the nerve before the femur has united. Aside from the effect of time on the nerve ends and muscle, the knee may become stiff, and cannot be flexed sufficiently to allow one to over come large defects Further resection of part of the femur may be necessary to overcome a defect between the nerve ends. In the presence of a fracture, this is justifiable and easily accomplished, but is a questionable procedure if the femur is intact.

After Treatment—Following every neurorrhaphy of the sciatic nerve the extremity should be immobilized in a double plaster hip spica cast extending from the nipple line to the toes on the affected side and to the knee on the opposite side. On the affected side, the knee is flexed and the hip extended. The cast is windowed to permit removal of the sutures after about ten days, and at selected points for stimulation of the paralyzed muscles by the galvanic current At the end of six weeks, the cast is removed and a long leg brace with a turnbuckle at the knee is applied, so the knee may be extended gradually over an additional six weeks Physical therapy and exercises are utilized to restore function to the joints and soft parts After the knee has been extended, an appropriate brace is applied to compensate for the lower leg paralysis.

PERONEAL NERVE

The peroneal nerve is a division of the sciatic and is composed of fibers from L4 and 5 and S1 and 2 It is more commonly injured than the tibial even in the sciatic nerve, and is affected by injuries around the knee, fractures of the head of the fibula, and improperly applied casts in this region.

Examination.—The muscles supplied by this nerve which can be accurately tested have been listed above Typically, injury of the peroneal nerve results in a foot drop which, incidentally cannot be overcome by any supplementary or trick movement The nerve may be easily stimulated in situ at the head of the fibula. The autonomous zone of this nerve is extremely variable and for this reason is only of value when present

Approach.—The exposure of the peroneal nerve in the lower thigh and popliteal space is described above If the nerve is injured at the head of the fibula or below the incision may be begun at any point above the injury as

required at the head of the fibula it is curved anteriorly across the neck of the fibula and down the anterolateral aspect of the leg The incision is then carried through the fascia and the nerve is identified above on the medial side of the biceps femoris tendon The nerve may then be traced distally as it c



Fig 531.—Autonomous zone of peroneal nerve.

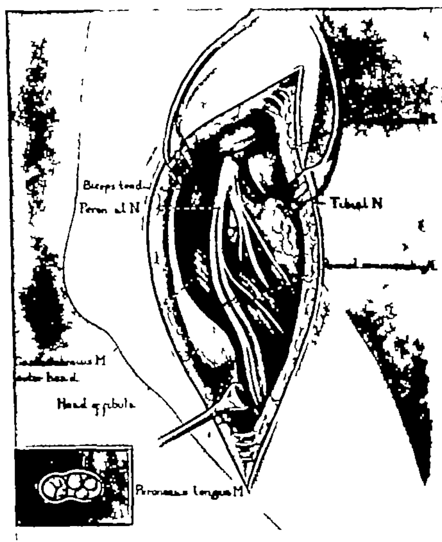


Fig. 532—Exposure of peroneal nerve in popliteal space, with ... two branches. Insert shows arrangement of funiculi at level of suture ... nerve does not divide into distinct deep and superficial branches until ... fibula. (From Stookey, Byron Surgical and Mechanical Treatment ... Philadelphia, 19?2, W B. Saunders Co.)

around the neck of the fibula between the origin of the peroneus longus and the bone just distal to this point it divides into the deep and superficial nerves. The superficial nerve continues down the leg between the peroneus longus muscle and the extensor digitorum longus in the intermuscular septum. The deep peroneal passes obliquely downward beneath the extensor digitorum longus; the origin of the latter muscle must be disconnected to expose completely this portion of the nerve, where numerous muscular branches are given off. The nerve may then be traced downward under the tibialis anticus muscle, just lateral to the anterior tibial artery

Methods of Overcoming Defects.—Extensive mobilization and flexion of the knee allows one to make up as much as 10 to 12 cm. in the popliteal space Below the neck of the fibula, length is obtained with much difficulty Even here mobilization in the thigh and in the leg, stripping up of branches in the leg and flexion of the knee will allow one to overcome a considerable defect in either of the divisions of the common peroneal nerve.



Fig. 533.—A Mayfield incision for exposure of nerves in popliteal space, note cicatrix from wound of entrance. B Ulceration and contracture are likely from incisions across skin folds.

Even though one is able to overcome a (ble defect suture lin
the peroneal nerve are five to ten times as lik rate as those in all
peripheral nerves combined. This is even tr rrhaphy of the p
division of the sciatic nerve, and is apparentl e fact that the p
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the two bony points removed This author has had no experience with the procedure but believes it is worth a trial In most cases however, it is probable that immobilization in a plaster hip spica for six weeks, and gradual extension of the knee over a period of an additional six weeks, will prevent such catastrophes

After Treatment.—(See Sciatic Nerve)

THE TIBIAL NERVE

The tibial nerve composed of fibers of L4 and 5 and S1, 2 and 3 is the larger and more important of the two divisions of the sciatic nerve Injuries to this nerve are most disabling, because of the large sensory deficit on the sole of the foot, further, a considerable number of such injuries are associated with causalgia.

Examination.—(See sciatic nerve above for muscles supplied by this nerve which may be accurately examined) The autonomous zone of the tibial nerve (including the medial sural cutaneous branch) is variable but generally includes the sole of the foot except on the medial border of the instep the lateral surface of the heel and the plantar surface of the toes. Because of its depth in the popliteal space, stimulation of the nerve in situ is not yet dependable.

Approach.—The tibial nerve may be exposed in the popliteal space by the incision and approach described for the sciatic nerve above As usual, one must avoid crossing the skin folds of the popliteal space and, if extension of the incision down the leg is contemplated, the skin incision should extend along the medial side of the hamstring tendons, then down the leg just posterior to the medial border of the tibia

Methods for overcoming defects in the tibial nerve immobilization and postoperative care are identical to those employed in operations upon the sciatic nerve

POSTERIOR TIBIAL NERVE

The tibial nerve passes beneath the arch of the soleus muscle and continues down the leg as the posterior tibial nerve Injuries of this nerve are frequently associated with penetrating wounds of the leg fortunately they are uncommon in civilian life. Until World War II suture of this nerve was considered most difficult. Suture of the posterior tibial nerve below the origin of the muscular branches is as important as that of any peripheral nerve because of the constant threat of trophic lesions on the anesthetic plantar surface of the foot

Examination.—The tibialis posticus, flexor digitorum longus, and flexor hallucis longus are supplied by branches of the posterior tibial nerve shortly after its origin, the last two muscles are at times difficult to test, though the tendon of the flexor hallucis longus may usually be felt just behind the medial malleolus and as it crosses the medial side of the plantar arch. Unless atrophy of the intrinsic muscles of the foot is well advanced, the tendon of the flexor digitorum longus may be palpated less distinctly thus, one cannot always test this muscle

The isolated zone of supply of the posterior tibial is considerably less than that of the tibial because of the overlap from the sural nerve. Electrical stimulation of this nerve in situ may be easily accomplished where the nerve is superficial just medial to the internal malleolus.

Approach.—One may explore the posterior tibial nerve beneath the soleus muscle or in the lower third of the leg through a vertical incision, beginning just posterior to the subcutaneous portion on the medial side of the tibia, and continuing downward parallel to the tibia, to the ankle. This incision is carried through the superficial fascia, and the Achilles tendon identified and retracted laterally this exposes the deep fascial plane, through which the nerve and the artery may easily be palpated. This layer of fascia is opened vertically and the nerve is identified lateral to the artery This portion of the nerve may be easily mobilized distally to the ankle but as one traces the nerve proximally, it comes to be quite deep beneath the soleus muscle on the tibialis posticus, between the flexor hallucis longus laterally and the flexor digitorum

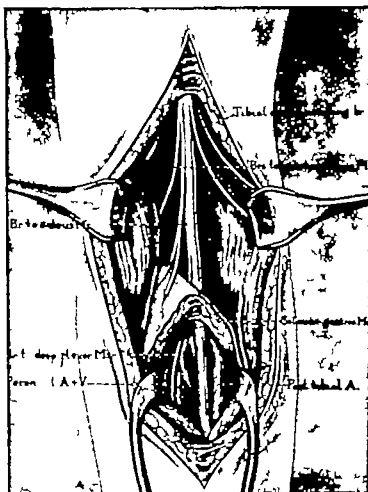


Fig. 534.—Anatomy of sciatic, peroneal, tibial and posterior tibial nerves in popliteal space and upper third of leg. See text for exposure. (From Stookey, Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

longus medially At about the middle of the leg ... n of the soleus from
the tibia interferes with ex ... ure and is secti ... muscle is reflected
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Methods of Overcoming Defects—Even though the lesion is fully exposed by this approach one can rarely overcome a significant gap by mobilization of the nerve alone Extension of the ankle to obtain length is not only of little practical value, but is also dangerous and to be condemned It is therefore almost always necessary to expose and mobilize the tibial nerve in the popliteal fossa or above (p 747) The two incisions are thus connected and the nerve is then mobilized from the thigh to the ankle. In addition all muscular branches must be gently stripped back intraneurally for several inches, by careful dissection. By flexion of the knee to 90 degrees one may then overcome a gap of 10 to 12 cm Occasionally additional length may be obtained by transplantation of the nerve between the soleus and gastrocnemius or superficial to both of these muscles. This is particularly applicable when the lower muscular branches to the flexor hallucis and digitorum longus have been destroyed, though it may be carried out with these branches intact if they are dissected up to the popliteal space After one is certain that the defect can be overcome, but before neurorrhaphy is performed particularly if tension on the suture line is likely the incision in the popliteal space should be closed, because closure of the fascia may reduce the regained length slightly

If the nerve is transplanted between the soleus and the gastrocnemius or superficial to both the soleus should also be sutured to its origin before neurorrhaphy is performed. If transplantation is unnecessary the soleus is, of course, sutured after the neurorrhaphy

After Treatment.—(See Sciatic Nerve p 750)

BRACHIAL PLEXUS

The brachial plexus is formed by the union of the anterior *rami* of C5 6 7 8, and T1. The fifth cervical nerve usually receives some fibers from C4 and the first thoracic from T2 These unite above the clavicle to form the *trunks* which are three in number the upper middle, and lower trunks. The upper trunk contains fibers from C4, 5 and 6 the middle those from C7 and the lower the fibers from C8 T1, and 2.

Each *trunk* divides into anterior and posterior *divisions,* which in turn form the cords. The anterior divisions supply the ventral aspect of the arm and the posterior divisions the dorsal aspect Specifically the anterior divisions of the upper and middle trunk unite to form the lateral cord of the plexus, the anterior division of the lower trunk forms the medial cord, while the posterior divisions of all three trunks form the posterior cord.

The following surgically important nerves are given off from the brachial plexus The long thoracic (to the serratus anterior) arises from the fifth, sixth and seventh cervical nerves shortly after they emerge from the intervertebral foramina The dorsal scapular (to the rhomboid and levator scapula) arises from the fifth cervical nerve a little more lateral than the long thoracic, though still between the scaleni muscles. The suprascapular nerve (to the supra and infra spinatus) arises from the lateral side of the upper trunk, well above the clavicle and is the first important branch one sees when the plexus is explored above the clavicle. There are no branches from the divisions of the trunks. The lateral anterior thoracic arises from the lateral cord and the medial anterior

thoracic from the medial cord. These unite to innervate the pectoral muscles. The musculocutaneous nerve arises from the lateral side of the lateral cord the medial brachial cutaneous, medial antebrachial cutaneous, and ulnar nerves from the medial side of the medial cord The median nerve is formed by the union of the medial and lateral cords. The upper subscapular the thoracodorsal (to the latissimus dorsi) and the lower subscapular nerves arise from the medial side, and the axillary from the lateral side of the posterior cord the posterior cord continues down the arm as the radial nerve



Fig. 635.—Pantopaque myelogram showing pseudomeningocele produced by avulsion of roots of C7 and C8 C5 and C6 which were also avulsed, did not fill. T1 still functions.

Examination.—Avulsing injuries of the brachial plexus are far more common in civilian life than penetrating wounds. Such injuries are usually the result of birth trauma or traction on the plexus, with or without dislocation or fracture-dislocation of the shoulder These injuries produce relatively constant symptoms and may be easily classified On the other hand penetrating wounds result in such complex injuries that classification is often difficult one may find a combination of rami trunks, divisions, and nerves above the clavicle, or nerves, cords and divisions below the clavicle Avulsing injuries result in injuries to the cervical nerve roots or trunks and are generally divided into upper (Erb) and lower (Klumpke) arm paralysis.

The diagnosis of avulsing injuries to the nerve roots from the cord or within the intervertebral foramina from traction injuries about the neck and shoulder

usually presents no difficulty. Such a diagnosis is made in upper brachial plexus injuries on the basis of segmental motor and sensory deficit of the fifth, sixth and sometimes seventh cervical spinal nerves, and paralysis of the serratus anterior, levator scapulae, and the rhomboids, which indicates that the lesion in the nerve roots is medial to the emergence of the nerve supply (long thoracic and dorsal scapular nerves) of these muscles. In the lower brachial plexus injuries, the diagnosis is made on the basis of segmental sensory and motor deficit of the eighth cervical, first thoracic and sometimes the seventh cervical spinal nerves, together with a Horner's syndrome.

Since it is sometimes impossible to test accurately the function of the levator scapulae, rhomboids, and serratus anterior, myelography has recently been employed to determine whether the nerve roots have been avulsed (Murphey, Hartung, Kirklin). If the injury is medial to the emergence of the nerves which supply the above muscles, surgical repair is impossible. However, if the lesion is distal to these nerves, exploration is warranted and repair is sometimes possible. Such a diagnosis would be based upon a negative myelogram and apparently normal functioning of the above muscles. Penetrating injuries of these nerves rarely produce similar neurologic findings.

Injuries to the trunks produce the same segmental sensory and motor deficit as injuries to the rami without involvement of the long thoracic and dorsal scapular nerves. Isolated injuries to the divisions of the trunks are extremely rare and are usually associated with or mistaken for injuries to the cords or trunks.

Injuries to the cords produce fairly regular patterns of loss of function. Lateral cord injuries result in a motor and sensory deficit in the distribution of the musculocutaneous nerve (paralysis of biceps) and of the lateral head of the median nerve (paralysis of the flexor carpi radialis and pronator teres). Severance of the posterior cord results in motor and sensory deficit in the following nerves: subscapular (paralysis of the subscapularis and teres major), thoracodorsal (paralysis of the latissimus dorsi), axillary (paralysis of the deltoid and teres minor) and the radial nerve (see below). Paralysis of the medial cord produces the motor deficit of a combined ulnar and median nerve lesion (except for the flexor carpi radialis and pronator teres) and extensive sensory loss along the medial side of the arm and hand.

Indications for Operation.—The indications for operation on the brachial plexus are the same as for any other nerve. Unwarranted delay is even less excusable, especially when the lesion is on the lower side of the plexus, since it has been shown that the more proximal the injury, the more important is the interval between injury and neurorrhaphy in the result.

In any circumstance the results of surgical treatment of extensive brachial plexus injuries are usually disappointing in that even though the nerves regenerate, distortion of function may result. Nevertheless, unless the defect is too large, single or multiple neurorrhaphies may be carried out if the lesion, including the neuroma, is distal to the intervertebral foramen. If at exploration a neuroma in continuity is found, one should be more conservative in its resection than in a more distal nerve and neurolysis is often advisable.

Approach.—The brachial plexus may be approached above or below the clavicle, depending on the point of injury, though if neurorrhaphy is to be

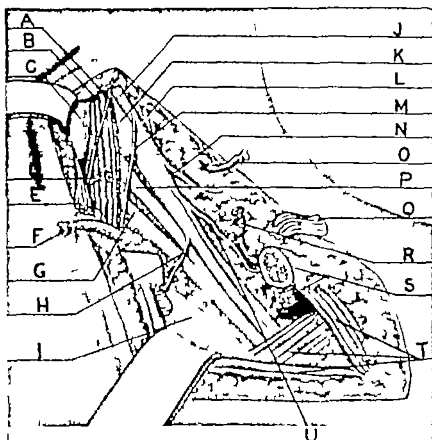


Fig. 536.—Exposure of brachial plexus with section of clavicle. *A*, Phrenic nerve. *B*, Scalenus anticus muscle. *C* Internal jugula vein. *D* Transversalis colli artery *E* Omohyoid muscle. *F* Suprascapular artery *G* Eighth cervical and first dorsal roots. *H* Muscular branch. *I* Subclavian vein. *J* Fifth root. *K* Sixth root. *L* Scalenus medius muscle. *M*, Nerve to subclavian muscle. *N* Suprascapular nerve. *O* Transversalis colli artery omohyoid muscle. *R* Suprascapular artery *S* Clavicle and subclavius muscle. *T* Pectoralis major pectoralis minor and deltoid muscles. *U* Anterior thoracic nerve. (From Stookey, Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

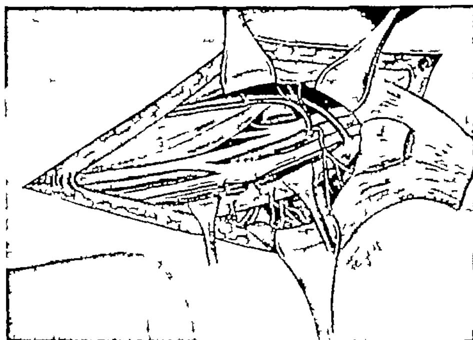


Fig. 537.—Exposure of cords and nerves from bracial plexus, showing lesion in medial cord. (From Stookey Byron Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

carried out near or above the clavicle, division of the clavicle and exposure of the entire brachial plexus is usually necessary The following technic includes the incision used in the exposure of the entire brachial plexus Any part of the incision may be employed for exposure of the underlying segment of this structure.

The incision is begun over the anterior border of the sternocleidomastoid muscle about 4 cm above the clavicle, and carried laterally over the sternocleidomastoid muscle and parallel to the clavicle, to a point above the junction of its distal and middle thirds. It is next curved downward across the clavicle along the anterior border of the deltoid muscle until the anterior pectoral fold is reached thence, the incision is curved posteriorly in the natural skin folds of the axilla to the midpoint of the medial aspect of the arm, where it is again curved distally in line with the neurovascular bundle Above the clavicle, the incision is carried through the subcutaneous layer and platysma. The external jugular vein is ligated, the omohyoid muscle retracted or divided, and the deep fascia exposed. The subclavian vein is several centimeters inferior and is seldom visualized The deep fascia is opened transversely the considerable amount of areolar tissue that is encountered is cleared away The scalenus anticus muscle is exposed medially by retraction or division of the clavicular head of the sternocleidomastoid muscle The phrenic nerve is identified as it crosses the scalenus anticus muscle from the lateral to the medial side, and retracted medially Division and ligation of the transverse cervical artery are usually necessary at this point, as it crosses the same muscle superficial to the nerve. The rami which form the brachial plexus may then be visualized as they emerge from beneath the edge of this muscle to form the upper middle and lower trunks. If better visualization of the rami is needed, the scalenus anticus muscle is sectioned exposing the subclavian artery below and the brachial plexus just above.

If visualization or mobilization of the plexus beneath or below the clavicle is desirable, the incision is carried through the fascia over the junction of the outer and middle thirds of the clavicle Distal to this structure, the incision is continued downward in the cleft between the pectoralis major and the deltoid muscles this line of cleavage being identified by the cephalic vein. The tendon of the pectoralis major muscle is severed about 1 cm. proximal to its insertion into the humerus The pectoralis major having been retracted medially, the clavi pectoral fascia is identified and incised vertically The tendon of the pectoralis minor is cut, retracted and marked. After exposure from above and below, the clavicle is divided with a Gigli saw, if necessary, a portion of the clavicle may be removed later The ends of the clavicle are separated, the subclavius muscle severed, and the cephalic vein ligated and divided.

The deep fascia of the upper arm is then incised exposing the neurovascular bundle The fascia encasing this structure is opened and both layers of fascia are divided vertically until the entire plexus is brought into view

The relationships of the various parts of the brachial plexus to each other and the vessels have been dealt with adequately in standard anatomy texts and need not be discussed at length here Certain features, however are worth repeating

Proceeding downward along the upper part of the arm one usually finds first the medial antebrachial cutaneous nerve crossing the large axillary vein.

This nerve is frequently mistaken for the ulnar nerve the latter however is easily exposed by mobilizing and retracting the vein laterally By medial retraction of the vein the axillary artery is brought into view, retraction of the artery medially exposes the median nerve well on the lateral aspect of the bundle By lateral retraction of the artery vein and ulnar nerve, one can easily identify the radial nerve, which lies well posterior to all other structures in the bundle As the artery is followed upward it comes to lie posterior to the point where the median nerve is formed by divisions from the medial and lateral cords. Above this point, posterior to the pectoralis minor tendon the artery separates the medial and lateral cords and is directly anterior to the posterior cord The point of emergence of the musculocutaneous nerve from the lateral cord is variable, usually being beneath the tendon of the pectoralis minor though it may be much lower Occasionally, several branches may emerge from the lateral cord to form this nerve The axillary nerve usually comes off the posterior cord a little higher then winds posteriorly through the quadrilateral space.

Methods of Overcoming Defects.—Extensive defects high in the brachial plexus and on its lateral sides present a difficult problem because of the limitation of mobilization imposed on the surgeon by the collateral nerves, such as the suprascapular lateral thoracics, subscapular and axillary nerves, which are given off by the plexus. In this region one may overcome a gap of 5 to 6 cm. by fully mobilizing the brachial plexus and these branches by resecting one inch of the clavicle, thus collapsing the shoulder toward the body by bending the neck sharply to the side of the lesion, elevating the shoulder girdle and by adducting the arm flexing the elbow and bringing the arm sharply across the chest. Frequently all the sutures in the nerve ends must be inserted, the clavicle plated and the wound closed, except at the actual point of neurorrhaphy before the extremity is positioned and the neurorrhaphy is carried out.

When positioning of the extremity and head has been necessary to overcome a large gap between the nerve ends, nothing less than a cast from the head to iliac crests will prevent disruption of the suture line.

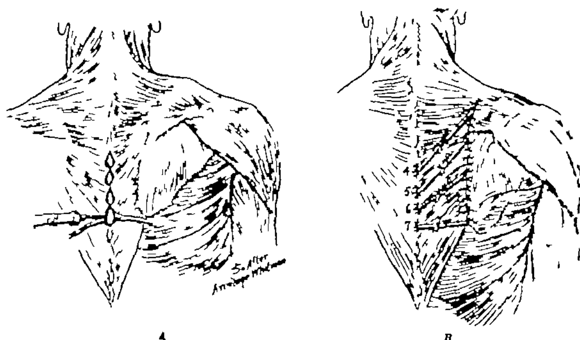
In the region of the cords length is much more easily gained. Rarely does one have to go above, or sacrifice part of the clavicle. By mobilizing the nerves to the elbow or below if necessary by elevation of the shoulder girdle and bringing the arm forward and across, and keeping it elevated from the chest, an amazing amount of length may be gained as a rule, defects of 10 cm. except in the posterior cord (see Radial Nerve) may be readily repaired in this manner Postoperative immobilization is maintained with a Velpeau dressing reinforced with plaster bandages

After Treatment.—The skin sutures are removed through a window in the cast on the tenth postoperative day At this time a roentgenogram should be made to determine the integrity of the suture line Additional windows are placed in the cast to permit the application of galvanic stimulation to the paralyzed muscles this should be carried out daily The cast is removed after six to eight weeks depending on the tension on the suture line, and another roentgenogram of the suture line is made An abduction humerus splint is applied and gradually lowered and the elbow gradually extended over a period of two to three weeks at the end of this time, active physical therapy and movement

of the shoulder and arm may be instituted Subsequently braces should not be worn during the day, except to prevent too rapid extension of a joint Rigorous occupational therapy is indispensable as soon as active motion is possible. Actually even though regeneration fails to take place a patient may learn various substitutional movements which permit fairly normal use of the extremity

Operation for Paralysis of the Serratus Magnus Muscle

Isolated paralysis of the serratus magnus muscle is occasionally observed as a result of stretching of the long thoracic nerve, or severance of the nerve at operation The patient cannot raise his arm above the level of the shoulder anteriorly, when this is attempted, winging of the scapula results, the vertebral and inferior angle becoming unduly prominent. The patient is also unable to exert forward pushing movements of the shoulder or to cross the arms anteriorly



A B

Fig 535—Operation for paralysis of serratus magnus muscle (Armitage Wh[illegible] Exposure of displaced scapula and of spinous processes. Holes drilled through [illegible] of scapula and spinous processes of fourth, fifth, sixth, and seventh dorsal [illegible] Operation completed. Strips of fascia lata have been passed through correspo[illegible] scapula and spinous processes with scapula drawn downward and medially, [illegible] under tension. (Redrawn from Whitman, Armitage, J A. M A. [illegible] 1332, 15[illegible])

As a rule *immobilization* of the shoulder girdle in the hyp[illegible] position with the arm approximated to the chest or with the should[illegible] and rotated externally until function returns is sufficient. Sho[illegible] persist, repair may be accomplished by the following proce[illegible] (see technic of Dickson, Chapter XXII)

Technic (Whitman)—The superior and vertebral borders [illegible] are exposed through an incision extending from the acromio[illegible] the superior border thence down the vertebral border Four [illegible] through the scapula one at each of the following points the [illegible] the junction of the spine and vertebral border, the middle [illegible] border and the inferior angle. The spinous processes of [illegible]

sixth and seventh dorsal vertebrae are also pierced with holes Strips of fascia lata are passed through these corresponding holes and sutured under tension as the scapula is retracted downward and backward

After Treatment.—A shoulder spica cast is applied holding the arm abducted 35 degrees beyond a right angle. After four weeks, the cast is removed and motion permitted.

RADIAL NERVE

The radial nerve, which is a continuation of the posterior cord of the brachial plexus, consists of fibers of C6 C7, and C8 and sometimes T1 segments. It is primarily a motor nerve and innervates the triceps, the supinators of the forearm and the extensors of the wrist, fingers and the thumb Lesions of this nerve are most often associated with fractures of the shaft of the humerus, and gunshot wounds or lacerations of the arm and upper forearm. Following suture, regeneration of the radial nerve is by far more satisfactory than that of any of the major nerves of the upper extremity chiefly because it is largely a motor nerve and secondarily because the innervated muscles are not primarily concerned with the finer movements of the fingers and hands

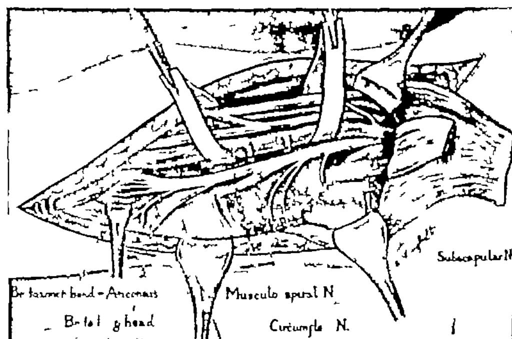


Fig. 539—Exposure of radial nerve (musculospiral) and axillary nerve (circumflex) in axilla and upper arm. (From Stookey Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

Examination.—The following muscles supplied by this nerve can be tested accurately since the muscle bellies or tendons, or both, can be palpated the triceps brachii brachioradialis, extensor carpi radialis longus, extensor digitorum communis, extensor carpi ulnaris, abductor pollicis longus, and extensor pollicis longus. Such an injury results in inability to extend the elbow supinate the forearm, and in a typical wrist drop The inexperienced examiner, however may often be misled by a patient's ability to extend the wrist merely by flexion of the fingers, again confirming the contention that analysis of movements, as

often as not, results in an error in the evaluation of the function of a nerve. The triceps is not seriously affected by injuries of the nerve at the level of the midpoint of the humerus, or below In injuries of the nerve at its bifurcation into the deep and superficial radial nerves the brachioradialis and extensor carpi radialis longus remain intact, thus the arm can be supinated and the wrist extended The nerve is particularly susceptible to electrical stimulation in situ just above the elbow; elsewhere, this is difficult and the results uncertain

Sensory examination is relatively unimportant, since there is, as a rule, no autonomous zone, even when the nerve is severed in the axilla. When an autonomous zone does exist, it is usually over the first dorsal interosseous muscle between the first and second metacarpal bones. It is not, however, sufficiently consistent to afford more than confirmatory evidence of complete interruption of the nerve provided of course the lesion is above the bifurcation of the nerve at the elbow

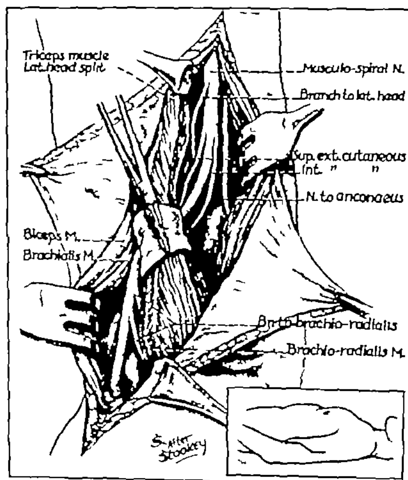


Fig. 540—Exposure of lower two-thirds of radial nerve. Insert shows line of skin incision. (Redrawn from Stookey Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co., p. 285.)

Approach.—The radial nerve may be exposed in the axilla and upper third of the arm by the usual low brachial plexus incision and by extension of this incision down the arm a little more posteriorly than is necessary for exposure of the ulnar and median nerves The fascia over the neurovascular bundle is incised, and the bundle is exposed between the triceps posteriorly and the biceps, brachialis, and coracobrachialis anteriorly The more superficial

structures of the bundle, namely the ulnar nerve, vein and artery and the median nerve are exposed and retracted laterally, bringing into view the radial nerve and one or two of its branches, first to the long head, and then to the medial head of the triceps The nerve may easily be traced to the point where it winds around the humerus.

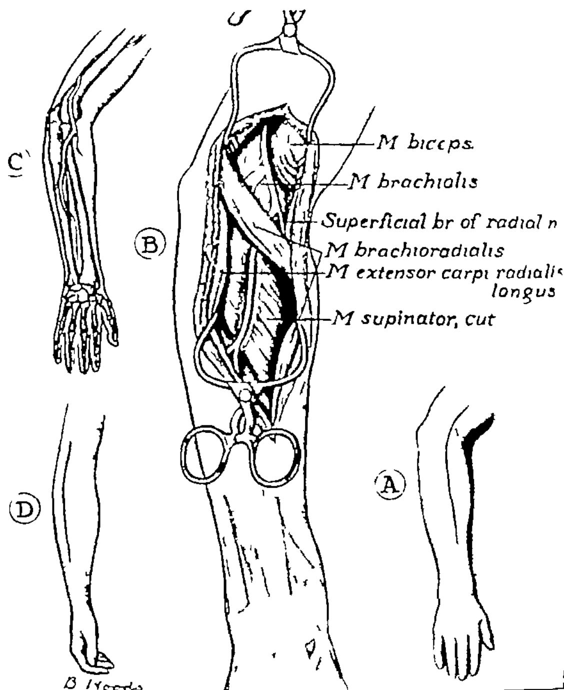


Fig. 541.—Exposure of posterior interosseous branch of radial nerve. *A* Line of incision, forearm prone, elbow flexed. *D* Line of incision, elbow extended. *C* Diagram of course of nerve with arm in position *A* *B* Nerve exposed (From Mayer J H., Jr and Mayfield, F H. Surg., Gynec. & Obst. 84 979 1947)

On the posterior and lateral aspects of the humerus, the nerve may be exposed by an incision which begins along the posterior border of the lower third of the deltoid, between the latter and the long head of the triceps. Thence, it

is extended downward in a curvilinear fashion along the lateral aspect of the arm curving at first medially along the medial aspect of the brachioradialis and then if necessary, laterally at the elbow, across the belly of this muscle and the extensor carpi radialis longus. Finally, if the deep radial nerve is to be explored the incision is carried down the dorsum of the forearm along the radial side of the extensor digitorum communis muscle

In the incision above the elbow, it is wise to expose the nerve at its most superficial position by incision of the fascia between the brachialis and brachioradialis, and to identify the nerve at this point by retraction of the brachioradialis laterally The nerve may then be easily traced upward by incision of the fascia and retraction of the lateral head of the triceps laterally to the point where the nerve winds around the humerus

Distally the nerve is traced downward to the elbow Five or six centimeters above the elbow, the branches to the brachioradialis, and then a little lower to the extensor carpi radialis longus and brevis are given off at the elbow the nerve divides into the superficial and deep radial (dorsal interosseous) nerves. The superficial radial nerve is entirely sensory and has little surgical significance Injuries to the deep radial nerve are fairly common and quite disabling It may be exposed through the lower part of the incision described above beginning eight to ten centimeters above the elbow and continuing to the midpoint of the dorsum of the forearm The nerve is followed beneath the brachioradialis into two planes of fibers of the supinator If the injury is at this point or below it is then best to expose the nerve below the supinator by incision of the fascia between the extensor carpi radialis longus and the extensor digitorum communis and development of this line of cleavage After exposure, the nerve is followed upward to the lower border of the supinator Here numerous branches are given off. After these are identified the superficial plane of the supinator is incised at a right angle to the direction of its fibers, thus completing the exposure of the entire deep radial nerve

Methods of Overcoming Defects.—Defects in the radial nerve are less easily overcome than those in the ulnar and median nerves. In general, however the same extensive mobilization and positioning of the extremity enable one to overcome the majority of gaps. In the axilla and high in the arm on its medial side i.e., above the point of emergence of branches to the triceps, it is extremely difficult to make up a gap of more than 6 to 7 cm without sacrificing the branches to the triceps this is hardly justifiable. Even resection of the humerus is rarely feasible at this level. Defects here are best overcome by mobilization of the nerve and posterior cord of the plexus to the clavicle and distally well to the lateral side of the arm. Defects of 10 to 12 cm. in the middle third of the arm may be overcome by mobilization of the nerve from the elbow to the clavicle and wide stripping of the branches by flexion of the elbow external rotation and strong adduction of the arm across and a little above the chest and finally if necessary sacrifice the branch to the brachioradialis (if the biceps is functioning) Transplantation of the nerve under the biceps anterior to the humerus although advocated by most authors on this subject actually adds little length and is seldom worth while In the presence of an ununited fracture three to four cm of the humerus may be resected However

if the above procedures are used, resection of a normal humerus should practically never be necessary to accomplish a repair of the radial nerve

In the lower part of the arm at the elbow and in the forearm the procedures mentioned above will permit one to overcome almost any defect up to a length of 10 to 12 cm.

After Treatment.—If adduction of the arm across the chest is necessary immobilization is maintained by a Velpeau dressing reinforced with plaster bandages. Otherwise as in repair of the ulnar and median nerves a posterior molded plaster splint will suffice, after-care proceeds as for the ulnar nerve (p 773)

Tendon Transplantation for Paralysis of Muscles Supplied by the Radial Nerve

This procedure is employed when suture of the severed radial nerve is impossible, or when function does not return after repair In the presence of injury to the median and ulnar nerves, or fixed contractures of the fingers or wrist, tendon transplantation is contraindicated By the original technic of Jones, the tendons are transplanted as follows

In injury of the radial nerve above the level of the origin of the posterior interosseous branch, the flexor carpi radialis muscle is inserted into the three extensors of the thumb and into an extensor of the index finger The flexor carpi ulnaris is transplanted into the extensors of the remaining three fingers, and the pronator radii teres is transplanted into the tendons of the extensor carpi radialis longus and brevis muscles. The Billington modification of the Jones technic has, in our experience been entirely satisfactory

When the lesion of the radial nerve is at the bifurcation or involves only the posterior interosseous nerve the problem is simplified, as the brachioradialis and radial extensors of the wrist are active Transference of the pronator radii teres is, of course, unnecessary Bunnell transfers the extensor carpi radialis brevis to the finger extensors and the long extensor of the thumb either a slip from the extensor carpi radialis longus or the palmaris longus is attached to the abductor pollicis longus.

In some instances, after neurorrhaphy of the radial nerve transference of the pronator radii teres to the radial wrist extensors may be worth while. Thereby the patient has some use of his wrist during a prolonged convalescent period.

In lieu of the rather extensive skin incisions described below the technic may be performed as suggested by Altman and Trott the motor tendons are mobilized through four small transverse incisions on the flexor surface of the forearm and wrist, then passed subcutaneously to a single transverse incision on the dorsum of the wrist According to these authors the incisions heal more rapidly with a minimal postoperative edema.

Technic (Billington).—An incision one and one-half inches long is made over the radial border of the forearm opposite the insertion of the pronator radii teres muscle, and a second incision, three-fourths inch in length, exposes the tendon of the flexor carpi radialis muscle three to four inches proximal to the wrist. A third incision is extended along the ulnar border of the forearm from four inches above the pisiform bone down to the level of this

bone thence across the dorsum of the wrist at a right angle to a point upon the abductor pollicis longus tendon just proximal to the base of the first metacarpal bone. This triangular skin flap is dissected up, bringing into view the extensors of the fingers proximal to the annular ligament and the extensors of the thumb at the "snuff box."

Through the first incision, the pronator radii teres muscle is detached from its insertion into the radius and passed through buttonhole openings in the tendons of the extensor carpi radialis longus and brevis muscles as far distally as possible. The tendons should be sutured to provide slight equal tension with the wrist in full hyperextension.

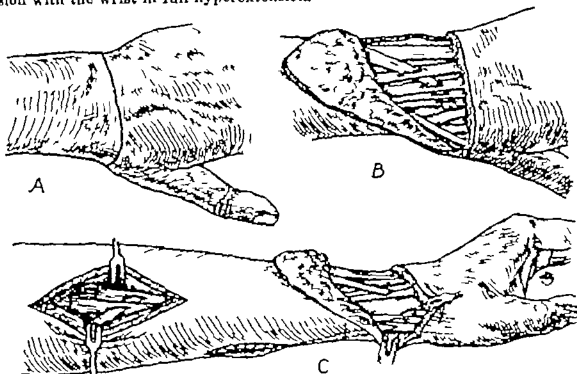


Fig 542.—Tendon transference for paralysis of muscles supplied by radial nerve (Billington) *A* L-shaped incision over dorsum of wrist. *B* Flexor carpi ulnaris tendon inserted into extensor digiti quinti proprius and extensor digitorum communis tendons. *C* Pronator radii teres muscles inserted into tendons of extensor carpi radialis longus and brevis muscles. Flexor carpi radialis tendon delivered subcutaneously into L-shaped incision and inserted into abductor pollicis longus and extensor pollicis brevis tendons. Extensor pollicis longus tendon severed and its distal portion sutured beside extensor pollicis brevis tendons and to end of flexor carpi radialis tendon. (Redrawn from Billington, R. W J Bone & Joint Surg. [illegible] 538 1922.)

The flexor carpi ulnaris tendon is divided at its insertion and the muscle fibers are sheared from the tendon up to a point two and one half inches above the wrist. Through a subcutaneous tunnel, the end of this tendon is passed across the posterior surface of the ulna to the dorsum of the wrist. The tendons of the extensor digiti quinti proprius and extensor digitorum communis muscles are carefully incised to preserve the overlying fascia, and are then buttonholed obliquely from within outward the transferred tendon of the flexor carpi ulnaris muscle is drawn through the holes and sutured to these four tendons. Billington states that it is unnecessary to include the extensor indicis proprius tendon. After suture all tendons should be under slight and equal tension with the wrist and fingers hyperextended. To prevent adhesions to the skin, the fascia is sutured over the tendons with fine catgut.

The radial end of the third incision is retracted and the tendon of the flexor carpi radialis muscle divided at its insertion. The tendon is identified

and delivered through the second incision, then rerouted through a subcutaneous tunnel to the dorsum of the wrist at the styloid process of the radius. The three extensor tendons of the thumb are next exposed opposite the carpus. A buttonhole incision is made in the tendons of the abductor pollicis longus and the extensor pollicis brevis muscles, and the transferred tendon is drawn through these tunnels. The extensor pollicis longus tendon is severed, and its distal portion is placed beside the extensor pollicis brevis tendon and sutured to the end of the flexor carpi radialis tendon. Again, the structures must be sutured under proper tension.



Fig. 543.—End result of tendon transference for radial nerve paralysis according to technic of Billington.



Fig. 544.—End result of transference of tendons for partial radial nerve paralysis, i.e., paralysis of extensors of fingers and extensor and long abductor muscles of the thumb.

After Treatment.—A special cock up splint is applied which holds the wrist hyperextended, the fingers partially extended and the thumb in full extension and abduction midway between dorsal and palmar rotation. Two weeks later the splint is removed and the same position is maintained while the patient is instructed in light voluntary contraction of the transplanted muscles. When light contracture can be detected, the splint is replaced. This procedure is repeated daily the number and strength of the contractures being gradually increased. At the end of the fourth week, physical therapy is instituted and exercises are carried out by the patient, the splint being worn between exercise periods.

Zachary reports results of 53 cases of tendon transplantation for paralysis of the radial nerve In 24 patients, both wrist flexors were utilized to provide extension of the fingers. In the latter group if the palmaris longus tendon

was absent the results were rather poor in that the patients could not actively flex their wrists nor could they completely extend the metacarpophalangeal joints of the fingers or the thumb unless the wrist was passively maintained in a neutral position If the palmaris longus was present, the result was somewhat better A fairly large number of the patients still had a defective range of extension of the metacarpophalangeal joints and of the thumb

In twenty nine patients, the flexor carpi radialis was left intact The flexor carpi ulnaris was utilized routinely to provide extension of the fingers For extension of the thumb, the brachioradialis was transplanted in five patients, an active wrist extensor in two, the palmaris longus in twelve and in nine patients who did not have a palmaris longus the flexor carpi ulnaris was transplanted to the extensors of all five fingers. In this group twenty seven patients could extend the fingers to the neutral position, eighteen could extend the thumb completely and all the patients could strongly flex the wrist to at least the neutral position From these results they contend that the absence of the wrist flexors leads to excessive dorsiflexion of the wrist when the patient attempts to extend the metacarpophalangeal joints If the flexor carpi ulnaris is retained the wrist is controlled sufficiently to permit better extension of the metacarpophalangeal joints as well as to preserve strong active wrist flexion to the neutral position or more

They also contend that if the palmaris longus is absent only the flexor carpi ulnaris should be transplanted unless the wrist is controlled by arthrodesis If the radial nerve is only partially paralyzed (posterior interosseous paralysis) the flexor carpi ulnaris may be transplanted together with one of the active wrist extensors It is their feeling that in complete radial nerve paralysis, the only alternative to arthrodesis is the utilization of the flexor carpi ulnaris to all of the digits They have found this procedure fairly satisfactory

In the presence of a palmaris longus, the latter was utilized in preference to the flexor carpi radialis and was combined with a flexor carpi ulnaris transplant

It was their conclusion that unless active strong flexion of the wrist is maintained extension of the fingers will be incomplete and the power of wrist flexion will be unnecessarily weakened.

ULNAR NERVE

The ulnar nerve is composed of fibers from C8 and T1 from the medial cord of the brachial plexus In civilian life, it is lacerated most often at the wrist like any other nerve however it may be divided at any point by a knife or gunshot wound. (See also delayed ulnar nerve palsy) Occasionally, in an individual with a shallow olecranon groove, the ulnar nerve will dislocate spontaneously when the elbow is flexed and will become subject to repeated trauma which leads ultimately to paralysis.

Examination.—Interruption of the ulnar nerve above the elbow is followed by paralysis of the flexor carpi ulnaris, the flexor profundus to the little and ring fingers, the lumbricales to the same fingers, all the interossei, the adductor to the thumb and all of the short muscles of the little finger Occasionally when the nerve is completely divided at this level the intrinsic muscles of the hand

function normally because of anomalous innervation of these muscles by the median nerve. Actually in such cases, the fibers which supply these muscles are incorporated in the median nerve to approximately midway of the forearm, where they leave this nerve to join the ulnar nerve just above the wrist. Complete lacerations of the nerve at the wrist always lead to paralysis of all the intrinsic muscles in the hand except the opponens pollicis, the abductor policis brevis, the lateral or superficial head of the flexor pollicis brevis, and the lateral two lumbricales

In actual practice, however only three muscles, the flexor carpi ulnaris, the abductor minimi digiti and the first dorsal interosseous, can be tested accurately The muscle bellies or tendons (or both) may be easily palpated or seen. One may be tempted to test other muscles by their well known functions, but will be misled by the occasional patient who can, by substitution of the other muscles, perform perfecly those of paralyzed muscles

Atrophy of the muscles supplied by the ulnar nerve and the claw finger deformity of the little and ring fingers are confirmatory evidence of paralysis of the muscles supplied by this nerve Stimulation of the nerve in situ is easily accomplished at the elbow and wrist

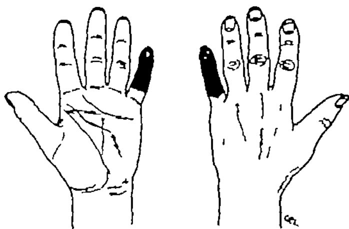


Fig. 541.—Autonomous zone of ulnar nerve.

The sensory examination is even less difficult. One need examine only the middle and distal phalanges of the little finger which is the autonomous zone of the ulnar nerve. Complete anesthesia to pin prick in this area strongly suggests total severance of the nerve. If one is in doubt about the sensory examination skin resistance studies or a starch iodine test will be useful.

Approach.—In the axilla, the ulnar nerve is exposed through the usual brachial plexus incision. For exposure of the nerve in the upper arm, the incision begins over the tendon of the pectoralis major curves into the natural folds of the axilla, thence downward along the medial aspect of the upper arm At a point 6 or 8 cm above the elbow the incision curves posteriorly slightly behind the medial epicondyle. For exposure of the nerve in the forearm, the incision is continued downward along the ulnar side of the volar aspect of the forearm to the first flexor crease of the wrist

In the axilla and upper arm the nerve lies just medial to the brachial artery usually beneath the brachial vein. At approximately the middle of the



Fig. 546.—Skin incision for exploration of median and ulnar nerves in upper arm.

Fig. 547.—Exposure of ulnar and median nerves in upper arm. (From Stookey, Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W. B. Saunders Co.)

upper arm, the nerve leaves the neurovascular bundle and courses somewhat posteriorly through the intramuscular septum over the medial head of the triceps muscle, and enters the olecranon groove behind the medial epicondyle of the humerus. There are no important branches of the nerve above the olecranon groove In this groove, the nerve gives off articular branches to the elbow joint and one or two branches to the flexor carpi ulnaris Muscular branches to the medial half of the flexor digitorum profundus and additional branches to the flexor carpi ulnaris are given off below the groove.

The nerve is followed into the forearm by disconnecting the flexor carpi ulnaris at its origin from the condyle of the humerus. The nerve passes down the arm on the radial side of the belly of the flexor carpi ulnaris upon the flexor profundus At the middle and upper third, the ulna artery approaches the nerve from its lateral side and accompanies it into the hand The dorsal cutaneous branch is given off approximately 8 to 5 cm. above the pisiform bone, and winds deep to the tendon of the flexor carpi ulnaris to reach the dorsum of the wrist and hand. The main trunk of the ulnar nerve passes down lateral *to the tendon of the flexor carpi* ulnaris *to enter the hand, where it divides* into the superficial and deep branches



Fig 541.—By bending bar simple brace provides gradual and controlled extension of elbow

Methods of Overcoming Defects.—The ulnar nerve may be sutured at any point along its course. It is probably more easily sutured than any other nerve, primarily because it may be transplanted into the antecubital fossa, thereby regaining length. If the lesion is below the muscular branches in the forearm, defects of 12 to 15 cm can be overcome by mobilization, transplantation and flexion of the wrist and elbow and by stripping of the motor branches up the nerve, sacrificing the articular branches In the upper arm, gaps of 8 to 10 cm. may be overcome by the same methods without sacrificing motor branches of the long flexors Sacrifice of these branches is seldom justifiable, since recovery of a motor function will probably be limited to these muscles after suture of the ulnar nerve in the upper arm.

The nerve is transplanted only after the most painstaking stripping of the branches to the flexor profundus and flexor carpi ulnaris. In this author's experience the nerve is best placed on the surface of the fascia of the flexor pronator group beneath the thick, fatty layer in this region, the fat is then tacked to the fascia medial to the nerve to keep the latter from slipping back behind the epicondyle. Or an incision may be made across the fascia of the flexor pronator group, the nerve placed in the groove made by the incision and the fascia is closed over the nerve. By another method, the common origin of the flexor muscles is detached from the medial epicondyle, the nerve placed beneath it and the common flexors sutured to the humerus.

After Treatment.—If transplantation and flexion of the wrist and elbow have been necessary, a molded posterior plaster splint extending from the axilla to the metacarpophalangeal joints is required. If the lesion is in the forearm and the deficit has been overcome by flexion of the wrist alone, the wrist is immobilized in a posterior molded plaster splint from a point just below the elbow to the metacarpophalangeal joints.

The sutures are removed ten days postoperatively and if possible daily galvanic stimulation is applied to the paralyzed muscles. The cast is removed after four weeks, and the elbow and the wrist or both are gradually straightened by means of metal splints over a period of two to three weeks, depending on the extent of the defect and tension on the suture line. During the entire period of immobilization and extension roentgenograms are made at frequent intervals to determine the integrity of the suture line.

After the arm is straight the patient is given a splint (Fig. 548) for night use only to prevent development of deformities.

Transference of the Ulnar Nerve for Tardy Ulnar Nerve Palsy

Delayed or tardy paralysis of the ulnar nerve frequently follows improperly treated fractures of the external condyle of the humerus in childhood. Because of the increase in the carrying angle and consequent cubitus valgus deformity the ulnar nerve is gradually stretched in its groove on the internal condyle of the humerus. This produces an irritative syndrome or incomplete lesion of the nerve. A traumatic lesion of a similar nature may be induced by simple contusion of the nerve, fractures of the internal epicondyle, or dislocations of the elbow joint. Symptoms arise from compression or impingement of scar tissue or callus.

Treatment consists of removal of the ulnar nerve from its groove, transplantation of the nerve to the flexor surface of the elbow and neurolysis if necessary.

Technic.—With the arm abducted and rotated externally an incision is made over the posteromedial surface of the elbow beginning two inches above the epicondyle, extending across this bony prominence and proceeding distally in line with the course of the nerve. The anterior skin flap is dissected upward to expose the common origin of the flexor muscles. The nerve is identified above the groove in the internal epicondyle and freed of soft tissues. Distally the nerve passes beneath a tendinous arch between the humeral and ulnar heads of the flexor carpi ulnaris muscle; this arch is severed and the heads of the muscle separated, further exposing the nerve. The muscular branches of

the nerve should be identified and preserved. Fibrous tissue or callus is dissected from the area adjacent to the groove that the nerve may be removed, and a neurolysis or endoneurolysis is carried out, as indicated. The trunk of the nerve is then drawn over the condyle to the anterior surface of the elbow and rerouted subcutaneously. The nerve is maintained in a forward position by a few interrupted sutures through the fascia and subcutaneous fat.

After Treatment.—The elbow is immobilized at a right angle for a period of two weeks. Physical therapy is then instituted to combat secondary changes in the muscles of the hand.

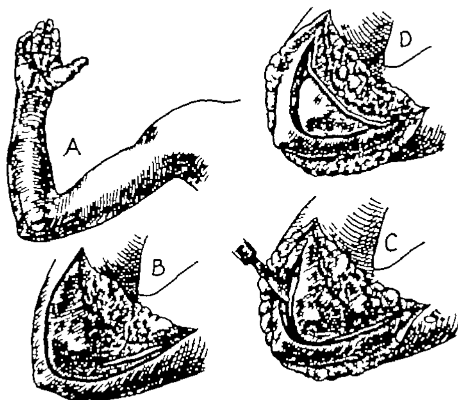


Fig. 549.—Transference of ulnar nerve for tardy ulnar nerve palsy. *A*, Line of skin incision. *B* and *C*, Exposure of ulnar nerve. *Nerve freed of soft tissue and scar behind* epicondyle and from beneath tendinous arch between humeral and ulnar heads of flexor carpi ulnaris muscle. *D*, Ulnar nerve re-routed anteriorly.

MEDIAN NERVE

The median nerve is formed by the junction of the lateral and medial cords of the brachial plexus in the axilla, and is composed of fibers from C6, C7, C8, and T1. In peace, the medial nerve, like the ulnar, is usually injured in lacerations of the volar aspect of the wrist or forearm, but unlike the latter injuries of the median frequently result in painful neuromas and causalgia. Furthermore, median injuries are more disabling because of the sensory loss.

Examination.—The muscles of the forearm supplied by the median nerve which can be tested with fair accuracy are the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis and flexor pollicis longus. The flexor profundus to the index finger is subject to overlap from the ulnar nerve, thus, tests of this nerve are not reliable. One should also keep in mind the fact that it is frequently impossible to test separately the flexor digitorum sublimis and the flexor profundus. In the hand, the opponens pollicis may be

satisfactorily tested in most individuals, though it should not be tested by mere observance of rotation and opposition of the thumb By substitution of the flexor pollicis brevis, many individuals can perform these motions quite well At times, the abductor pollicis brevis is difficult to test separately from the opponens, this is of no real significance, however, as both are supplied by the median nerve The lumbricals cannot be tested, since they cannot be palpated and their function may be reproduced by a combination of contraction of the interossei and extensors of the fingers Atrophy of the thenar eminence and forearm is usually obvious in median injuries. In addition, the median is particularly susceptible to stimulation in situ because of its superficial position in the lower forearm

The smallest autonomous zone of supply of the median nerve is the dorsal and volar aspect of the distal phalanx of the index and middle fingers. Thus, it is only necessary to examine carefully these areas for anesthesia. Frequently, even though the nerve is known to be divided, squeezing the tip of the index finger will produce pain, hence, so far as deep pressure is concerned an isolated zone is not always present. If one is in doubt about the sensory examination skin resistance or the starch iodine test, as in the case of the ulnar nerve will be useful.

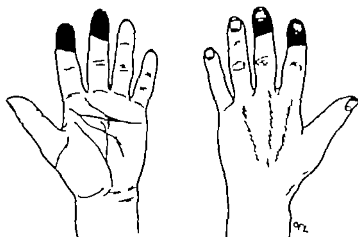


Fig. 550 —Autonomous zone of median nerve.

Approach.—The incision for exposure of the median nerve is the same as that for the ulnar nerve in the upper arm and at the elbow Thereby, an incision directly across the folds of the antecubital fossa is avoided.

For exposure of the median nerve in the forearm, the incision continues from the median epicondyle onto the volar aspect of the forearm, then downward in a curvilinear fashion over the course of the nerve In approaching the wrist it curves radially (or if a combination median ulnar exploration is indicated toward the ulnar side) As the flexor creases of the wrist are reached, the incision continues back along these creases to the midpoint of the wrist. If the nerve is to be explored below the wrist the incision should extend down the life line of the palm

The incision is carried down through the fascia along the course of the nerve At the elbow to accomplish this, the skin flap must be undermined widely In the upper arm, medial retraction of the brachial artery and vein

will bring the nerve into view on the lateral aspect of the neurovascular bundle. At the junction of the middle and lower thirds of the arm the nerve crosses to the medial side of the artery usually passing behind, though occasionally in front of the artery The nerve enters the forearm beneath the lacertus fibrosus medial to the artery then passes between the two heads of the pronator teres, and continues down the forearm beneath the flexor sublimis lying on the flexor profundus. Approaching the wrist the nerve becomes more superficial lying beneath the tendon of the flexor carpi radialis and is easily found if approached between the latter tendon and that of the palmaris longus.



Fig. 551.—Skin incision for approach to median nerve avoiding skin folds of flexor surface of elbow Same incision used for combined approach to median and ulnar nerves.

At the elbow the nerve is exposed by incision across the fibers of the lacertus fibrosus at its attachment to the fascia over the pronator flexor group The fascia is dissected from this group of muscles radially and incised downward along the upper border of the pronator thence again downward across the latter muscle and along the medial side of the flexor carpi radialis. Thus, the pronator teres may be widely mobilized and separated from the flexor carpi radialis permitting easy exposure of the nerve and facilitating subsequent closure It is then wise to expose the nerve where it emerges from beneath the fibers of the flexor digitorum sublimis. The nerve is traced upward by retraction of the flexor carpi radialis laterally the pronator upward and by separation of the fibers of the flexor digitorum sublimis In this way the nerve may be exposed over its entire course

The median nerve gives off no branches in the upper arm The branches to the pronator teres and flexor carpi radialis are given off as the nerve passes

under the lacertus There are usually two branches to the pronator, one to the superficial and one to the deep head In addition, there are several branches to the flexor carpi radialis and palmaris longus one to the flexor sublimis and one to the profundus The volar interosseous nerve comes off from the medial and posterior side of the nerve supplying the flexor pollicis longus, half of the flexor profundus muscles and the pronator quadratus Distal to this point, several additional branches are given off to the flexor digitorum sublimis. No other branches of significance are given off until the nerve enters the hand

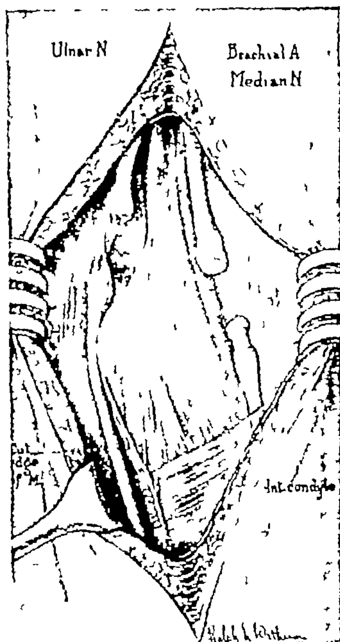


Fig. 412.—Exposure of median and ulnar nerves at elbow (From Stookey Byron Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.)

Methods of Overcoming Defects—By extensive mobilization stripping back of branches in the main trunk and flexion of the wrist and elbow one may overcome a deficit of 8 to 10 cm above the elbow and 12 to 15 cm below the elbow Transplantation of the nerve anterior to the pronator teres allows one to

make up additional length if the lesion is below this muscle. Transplantation may not be easily accomplished however this depends upon the level at which the branches to the pronator flexor groups are given off If these branches are given off distally transplantation is much more difficult than if they are given off at a higher point

As a rule, transplants are necessary in large destructive wounds of the mid forearm In these cases most of the branches to the flexor sublimis are usually destroyed and therefore need not be considered.

Transplantation is accomplished by stripping back the branches to the pronator teres, flexor carpi radialis, palmaris longus, and the volar interosseous nerve from the main trunk, well up in the upper arm by mobilizing the distal end of the nerve all the way to the wrist and under the transverse carpal ligament then after flexion of both the wrist and the elbow, by suture of the nerve over the flexor pronator group Two or three cm additional length may be gained by transplantation thus permitting a neurorrhaphy which could not otherwise be accomplished. If too much tension is placed on the nerve, the fascia and lacertus must be closed beneath it the nerve being left subcutaneously all the way to the wrist.

After Treatment.—See Ulnar Nerve

Tendon Transference for Paralysis of Muscles Supplied by the Median and Ulnar Nerves

In complete paralysis of the median and ulnar nerves, a satisfactory hand cannot be reconstructed by tendon transference as all the flexors to the fingers and thumb and the intrinsic muscles of the hand are functionless, accompanied by a substantial sensory deficit.

John B Murphy utilizes the extensor carpi radialis longus and brevis or the brachioradialis tendons to produce active flexion of the fingers and thumb No attempt is made to replace the power of flexion of the wrist, as this is secured by gravity and secondarily by contracture of the new flexors to the fingers.

Another method suggested by Bunnell, is a two-stage procedure. The wrist is fused in slight dorsiflexion and at a later operation, the extensors carpi radialis longus and brevis are attached respectively to the profundus tendons and the long flexor of the thumb To provide opposition of the thumb the brachioradialis is used as a motor with a section of sublimis tendon as a graft, connecting the motor to the base of the proximal phalanx of the thumb (Fig 553)

Tendon Transference for Paralysis of Muscles Supplied by the Median Nerve

In paralysis of the muscles supplied by the median nerve Bunnell utilizes the extensor carpi radialis brevis, the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus tendons. The profundus tendons to the fourth and fifth fingers and the flexor carpi ulnaris are supplied by the ulnar nerve and therefore remain active

Technic (Bunnell).—Through appropriate exposure, the extensor carpi radialis brevis is transplanted from the extensor surface of the wrist into the flexor pollicis longus tendon The profundus tendons to the index and middle fingers are detached proximally and reinserted into the flexor profundus tendons

of the ring and little fingers Thus, the ulnar side of the flexor profundus will flex the second to the fifth fingers, inclusive The flexor carpi ulnaris may be either inserted into the flexor sublimis tendons to increase the strength of the flexors of the fingers and produce a more central pull on flexion of the wrist, or preferably used as the motor power to produce opposition of the thumb In the latter event the brachioradialis can be used to provide additional strength to the long finger flexors

Tendon Transference to Restore Opposition

Restoration of active opposition of the thumb is the most vital point in the reconstruction of the hand as lack of this action is more disabling than any other single movement of the thumb and fingers. If the range of passive motion of the thumb is relatively normal tendon transference may restore excellent opposition.

Steindler replaces the lost opponens action by utilizing the flexor pollicis longus muscle, provided this structure is active and strong The technic of the procedure is relatively simple.

Technic (Steindler).—An incision is made along the radial side of the thumb beginning at the level of the interphalangeal joint and extending proximally to a point one half inch beyond the metacarpophalangeal joint. The lateral cutaneous nerve of the thumb should be isolated and protected The flexor pollicis longus tendon is followed to its insertion into the distal phalanx and proximally to its emergence from beneath the short thenar muscles. In dissecting the tendon proximally one should avoid injury to the branches of the median nerve which supply the thenar group in the event that part of this group has escaped paralysis

The sheath of the flexor pollicis longus is incised the full length of the incision, the tendon is split longitudinally into two equal parts, and the radial half is freed at the distal end and displaced from the sheath With interrupted sutures of fine silk or catgut, the sheath is then closed over the remaining half of the tendon. The radial portion of the tendon is attached to the periosteum of the proximal phalanx, as follows

With the thumb adducted to the maximum degree and both phalanges fully flexed, a subcutaneous tunnel is created around the dorsal aspect of the proximal phalanx by means of a curved forceps, and a short longitudinal incision is made over the point of the forceps. The free radial flap of the long flexor tendon is scarified, carried through this subcutaneous tunnel, passed through the second dorsal incision, and attached under tension at the base of the proximal phalanx just distal to the metacarpophalangeal joint The tendon may be sutured to the soft tissues or through a hole drilled in the phalanx.

After Treatment.—The thumb is maintained in full adduction and flexion for a period of three weeks. Muscle exercises and active and passive motion are then instituted.

Bunnell states that, to secure satisfactory results, two principles must be observed (1) The tendon must be passed from its insertion into the thumb subcutaneously in a direct line to the pisiform bone, that the thumb may be angulated forward and toward the ulna (2) the tendon must be inserted into

the dorsoulnar aspect of the base of the proximal phalanx of the thumb to restore pronatory movement To provide this action a tendon pulley is constructed at the pisiform bone, or the tendon is looped around the distal part of the flexor carpi ulnaris. Quoting Bunnell If the two main essential principles mentioned are adhered to one has quite a varied choice in the selection of muscle and tendon and in the construction of the pulley, depending on which are available or advantageous in the particular case of reconstruction. Each hand is a problem in itself, and as the parts injured differ so we must adapt our procedure to the available material, providing we adhere to these two simple principles, namely direction of pull and correct insertion to give pronation.'

1 For motor power any of the following tendons may be employed flexor carpi ulnaris, palmaris longus, flexor digitorum sublimis of the ring finger or any available long flexor muscle. Extensor muscles are not suitable for this purpose, as they are weak and their courses are long presenting opportunities for the formation of adhesions.

2 For transmitting the motor power of the above muscles to the proper insertion on the base of the proximal phalanx the extensor pollicis brevis tendon is ideal having already the correct insertion and will retain its original function The palmaris longus tendon may be prolonged sufficiently by utilizing the palmar fascia, or a free tendon graft may be inserted between the motor tendon and the attachment of the thumb

For construction of a pulley at the pisiform bone, a free tendon graft may be looped through the short muscle and tendon attachment to the pisiform bone and sutured to itself forming a circle 2 cm. in diameter The sutured junction is slipped around and placed within the tendon. Possibly splitting the flexor carpi ulnaris tendon in half severing the radial half proximally and leaving the distal portion intact on the pisiform bone would be a simpler method. The free end of the tendon is then sutured at the pisiform bone to complete the loop Or the palmaris longus tendon may be severed 4 cm. proximal to its insertion and sutured into the pisiform ligamentous tissue, thus acting as a loop One may also pass the tendon used for the motor power around the flexor carpi ulnaris tendon, thence onward to its insertion in the phalanx of the thumb In the latter event, the flexor carpi ulnaris aids the motor tendon in securing opposition.

The following combination appears to be the most simple and effective provided the flexor carpi ulnaris muscle is active For motor power the flexor carpi ulnaris for the tendon the extensor pollicis brevis and for the pulley one half the thickness of the distal two inches of the flexor carpi ulnaris tendon.

Technic (Bunnell) —An L-shaped incision is begun at the midline on the volar aspect of the wrist, extended along the distal flexor crease to the pisiform bone, thence continued three inches proximally in line with the flexor carpi ulnaris tendon. Beginning at the pisiform bone, the flexor carpi ulnaris is split in half proximally for two inches the radial half of the tendon is divided proximally and the ulnar half divided at the pisiform bone. The loop is formed by suture of the radial half of the tendon to itself or to the soft structures at the pisiform bone.

A second incision, one inch in length, is made over the radial side of the thumb at the level of the metacarpophalangeal joint, exposing the end of the

extensor pollicis brevis tendon A third incision, two and one half inches in length, is made over the dorsoradial aspect of the forearm just proximal to the wrist joint, and the tendon of the extensor pollicis brevis muscle is divided at its musculocutaneous junction The tendon of the extensor pollicis brevis muscle is then withdrawn from the second incision, a silk suture is placed through its end and the tendon is passed subcutaneously across the thenar eminence toward the pisiform bone to emerge in the first incision The free end of the ex

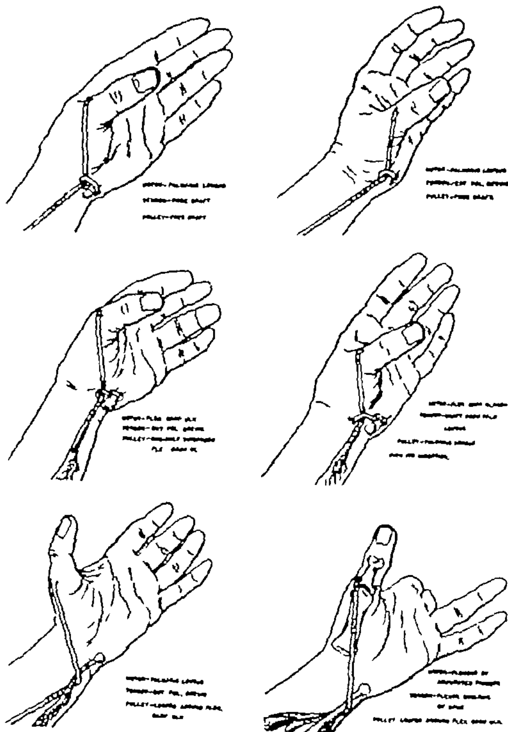


Fig. [illegible] —Tendon transference for restoration of opposition of the thumb (Bunnell) Drawings illustrate various combinations of motor power tendon, and pulley construction. The tendon should pull diagonally across the thenar eminence toward the pisiform bone, to angulate the thumb forward and toward the ulna. To pronate the thumb, the tendon should be inserted into the dorsoulnar aspect of the base of the proximal phalanx. (From Bunnell, Sterling J Bone & Joint Surg. 20: 269 1938.)

tensor pollicis brevis tendon is drawn through the loop and, with the thumb in opposition, is sutured to the distal end of the flexor carpi ulnaris tendon under adequate tension (see Fig 553)

After Treatment.—(See p 779)

Restoration of function is more complete by this procedure than by the Steindler technic.

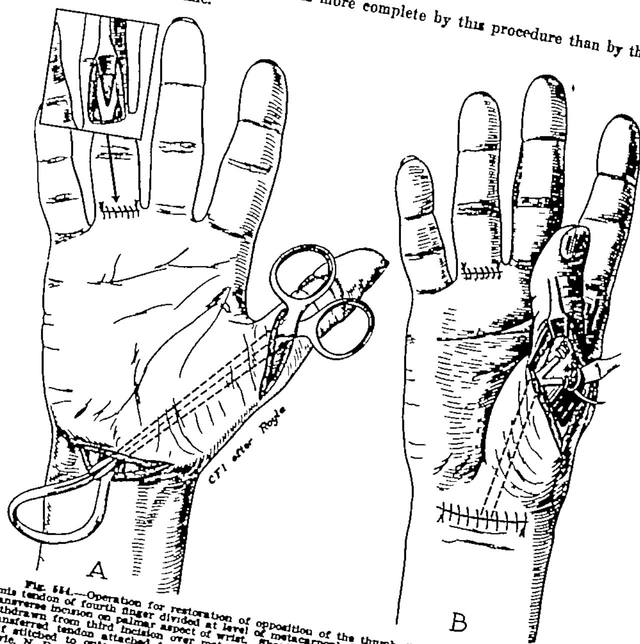


Fig. 554.—Operation for restoration of opposition of the thumb (Royle) *A*, Flexor sublimis tendon of fourth finger divided at level of metacarpophalangeal joint and withdrawn from transverse incision on palmar aspect of wrist. Sheath of flexor pollicis longus opened and tendon withdrawn from third incision over metacarpophalangeal joint of the thumb. *B*, Split end of transferred tendon attached to insertion of short flexor with the phalanx in flexion other half stitched to outer edge of opponens pollicis with thumb in opposition. (Redrawn from Royle, N. D J. A. M. A. 111 612, 1938.)

For paralysis of the intrinsic thenar muscles, namely the opponens, short flexor and short abductor muscles, Royle employs a tendon transplantation, utilizing the flexor sublimis tendon of the ring finger The principal advantage of this operation according to Royle is the ease with which reeducation is accomplished. When the patient attempts to flex the ring finger the thumb is drawn into opposition.

Technic (Royle)—A transverse incision is made over the metacarpophalangeal joint of the ring finger the distal edge of the incision is retracted

and the insertion of the bifurcated sublimis tendon incised The sheath of the flexor pollicis longus muscle is then exposed by a curved incision just proximal to the metacarpophalangeal joint of the thumb A third incision is made transversely across the volar aspect of the wrist and the sublimis tendon is withdrawn, passed up the sheath of the flexor pollicis longus tendon and brought out at the incision over the metacarpophalangeal joint of the thumb By dissection of the edge of the incision distally, the insertions of the short flexor and opponens tendons are exposed With the first phalanx in flexion one portion of the bifurcated sublimis tendon is attached to the insertion of the short flexor tendon while the other portion is sutured to the outer edge of the opponens pollicis, the thumb being held in opposition

After Treatment.—Immobilization of the thumb in opposition and the first phalanx in flexion is maintained for a period of ten days. Active movements are then permitted

Tendon Transference for Paralysis of the Ulnar Nerve

Restoration of function to the intrinsic muscles of the hand following paralysis of the ulnar nerve is a complicated technic that requires considerable experience in hand surgery the paralysis of the flexor profundus to the little and ring fingers is disregarded Attention is directed to loss of action of the hypothenar two lumbricales, interossei and thumb adductor muscles. Rehabilitation is even more complicated with a superimposed radial nerve paralysis or in mixed lesions secondary to injury of the lower brachial plexus.

For an authoritative dissertation on this subject, the reader is referred to Bunnell s excellent book, *Surgery of the Hand*

CAUSALGIA

Causalgia was first described by Mitchell, Morehouse and Keen, in 1864 This description is quite specific and, if followed, will avoid considerable confusion Causalgia is a clinical syndrome associated with a lesion of a peripheral nerve which contains sensory fibers, and is characterized by pain in the affected extremity usually the hand or foot The cause of this syndrome is not known. The sympathetic nervous system seems in some way involved, as suggested by many authors, though the evidence that this is true is not complete Two possibilities exist either the sympathetic system plays some role in the production of the pain or merely serves as the pathway for its conduction.

The pain is described by the patient in the following terms or combinations, in order of frequency burning throbbing aching pressure, knifelike stabbing twisting and crushing In most cases, the pain begins immediately after the injury but in perhaps one fourth may be delayed in its onset. The median and tibial nerves are far more commonly affected than all other nerves combined.

The pain is usually located in an area corresponding to the cutaneous distribution of the nerve, but is not necessarily limited to this distribution. Another important characteristic of the pain, and one generally necessary for a positive diagnosis, is its accentuation by emotional stimuli such as surprise and anger and other disturbing features in the patient's environment Some of the factors which aggravate or relieve the pain are so fantastic, they are hardly credible and may lead the patient to unwarranted psychiatric consultation For

example certain patients keep their injured extremity wrapped in a wet towel because moisture gives relief, others keep their normal hand moist, since to touch an object with a normal dry hand causes severe pain in the injured extremity It is impossible to examine some patients unless the examiner also moistens his hands Numerous patients put water in their shoes to avoid increasing the pain when they walk, even though the lesion is in the upper extremity Some cannot sleep on sheets or pillow cases preferring instead to sleep on a rough blanket To touch, feel or even hear the name of a slick object, such as a paper or sheet will cause some patients to experience a severe exacerbation of the symptoms. The sight or thought of a tall building will in some patients increase the pain Further, the pain is less severe on cool, damp days and at night, and is more readily relieved by a drink of whisky than by morphine.

Once one sees a patient with severe causalgia, he is not likely to forget the picture of a pain racked individual, guarding the affected extremity with extreme care The skin of the affected part is often cold and moist or it may be dark red, dry, atrophied, and glossy The skin may be devoid of hair or on the contrary, may have an abnormal growth of hair It is usually stated that causalgia is present only in incomplete lesions of peripheral nerves. Actually, there is some doubt about this, though the fact remains that the vast majority of patients have incomplete lesions, as paralysis or sensory loss is rarely complete. An accurate evaluation of the condition of the injured nerve, however is almost impossible because of the extreme pain which is induced by handling the part.

It should be stated that there are, no doubt, other painful states associated with injuries of the peripheral nerves or extremities, which Homans calls minor causalgia ' and deTakats "reflex dystrophy of the extremities or *causalgic states. These might be included under the term 'causalgia,'* and will in some cases, respond to the same treatment. For this reason, one may at times be confused as to the real diagnosis. In the severe case, the diagnosis is usually clear and is easily confirmed by procaine block of the second and third thoracic sympathetic ganglia if the pain is in the hand or block of the second or third lumbar sympathetic ganglia if the pain is in the foot Rarely will other conditions such as ruptured lumbar or cervical discs present any diagnostic difficulty

Many cases of mild or moderate severity subside spontaneously in a few months Occasionally especially in the early stages of the disease, a series of several sympathetic blocks with procaine will relieve the pain either completely or to a degree which will be tolerable If however the pain returns to the preinjection level sympathectomy is necessary

Preganglionic sympathectomy consisting of section of the sympathetic chain below the third thoracic ganglia and division of the *rami* between the second and third ganglia and their respective intercostal nerves, will usually relieve the pain in the upper extremity

If the lower extremity is affected, removal of the second and third sympathetic lumbar ganglia and chain through a high transverse abdominal incision *is usually adequate a more extensive sympathectomy may occasionally be necessary* (Mayfield)

References

Abbott L. C Injuries of the Median Nerve in Fractures of the Lower End of the Radius Surg. Gynec. Obst 57: 50?, 1933.

Albritten F F, Jr The Surgical Repair of the Deep Branch of the Radial Nerve Surg., Gynec & Obst 82 305 1910.

Albritten, F F., Jr : Method for Repair of Posterior Tibial Nerve Am J Surg 73 588 194

Altman, H., and Trott, R H Muscle Transplantation for Paralysis of the Radial Nerve J Bone & Joint Surg 28: 410, 1946.

Berkheiser, E. J., and Shapiro, Fred: Alar Scapula, J A M A 108 1,00 193?

Billington R. W : Tendon Transplantation for Musculospiral (Radial) Nerve Injury, J Bone & Joint Surg 20 538 1922.

Bristow W R.: Injuries of Peripheral Nerves in Two World Wars Brit. J Surg 34: 333 194

Bunnell S.: Surgery of the Hand Philadelphia, 1944 J B Lippincott Co.

Bunnell, Sterling: Surgery of the Nerves of the Hand Surg. Gynec. Obst. 44 145, 1927

— Opposition of the Thumb J Bone & Joint Surg 20 269 1938.

Coleman, C. C.: Surgical Lesions of Peripheral Nerves, in Bancroft, F W., and Pilcher C. Surgical Treatment of the Nervous System Philadelphia 1946, J B. Lippincott Co.

Conway, F M Traumatic Ulnar Neuritis, Ann. Surg 97 425, 1933

Davidson, A J., and Horwitz, M T Late or Tardy Ulnar Nerve Paralysis, J Bone & Joint Surg 17: 844 1935.

DeAngelis A M. Surgical Approach to the Tibial Nerve Below the Popliteal Fossa Am J Surg. 73 568 194?

de Takats, G : Reflex Dystrophy of the Extremities, Arch. Surg 34 939, 193?

de Takats, G : Causalgic States in Peace and War J A. M. A 128 699 1945

Fitch Ralph R.: An Operation to Improve the Condition of Hands Disabled by Paralysis of the Opponens Pollicis, J Bone & Joint Surg. 12 190 1930.

Gay J R., and Love, J G Diagnosis and Treatment of Tardy Paralysis of the Ulnar Nerve, Based on a Study of 100 Cases, J Bone & Joint Surg 29 1087 1947

Haymaker, Webb and Woodhall, Barnes: Peripheral Nerve Injuries, Philadelphia, 1945 W B. Saunders Co.

Jones, Sir Robert: Tendon Transplantation in Cases of Musculospiral Injuries Not Amenable to Suture Am. J Surg 35 333 1921

Kirklin, J W., and Murphey F Unpublished data.

Kirklin, J W., Chenoweth, A L., and Murphey F Causalgia. A Review of its Characteristics, Diagnosis and Treatment, Surgery 21 321 1947

Lewis, D Peripheral Nerves Dean Lewis' Practice of Surgery Vol. III Chap. 6, Hagerstown Md., 1939 W F Prior Co Inc.

Lewis, D., and Miller E. M.: Peripheral Nerve Injuries Associated with Fractures, Ann. Surg 76 528 1922.

Livingston, W K.: Evidences of Active Invasion of Denervated Areas by Sensory Fibers from Neighboring Nerves in Man, J Neurosurg 4 140 1947

Livingston, K. E.: A Simple Method of Rapid Identification of Major Peripheral Nerve Injuries, Lahey Clin. Bull 5 118 1947

Livingston, K. E., Livingston, W K., and Andrus, D : Nerve End Separation Following Suture Resection of the Neck of the Fibula in Suture of the Peroneal Nerve, J Neurosurg 4 10, 1947

Mayer J H., Jr., and Mayfield F H.: Surgery of the Posterior Interosseous Branch of the Radial Nerve; Analysis of 58 Cases, Surg., Gynec. & Obst. 84 9?9 1947

Mayer Leo: Loop Operation for Paralysis of the Adductors of the Thumb Am. J Surg 2 456 1927

Mayfield, F H.: Incision for Exposure of Peroneal Nerve at Knee, Bull. U S Army M. Dept. 4 167, 1945

Mayfield, F H., and Divine, J W : Causalgia, Surg., Gynec. & Obst. 80 631 1945

Medical Research Council War Memorandum No. 7 Aids to the Investigation of Peripheral Nerve Injuries ed. 2 London, 1943 His Majesty s Stationery Office

Murphey F., Hartung, W., and Kirklin, J W : Myelographic Demonstration of Avulsing Injury of the Brachial Plexus, Am. J Roentgenol. 58 102, 1947

Murphey F., Kirklin, J W., and Finlayson, A. L.: Anomalous Innervation of the Intrinsic Muscles of the Hand, Surg., Gynec. & Obst. 83 15 1946.

Murphy John B Infantile Palsy of Flexors of Hand and Fingers—Tenoplasty Surg Clin. John B Murphy 4 693 1915

Naffziger, H. C : Methods to Secure End to-End Suture of Peripheral Nerves, Surg Gynec. Obst. 32 193 1921.

Ney K. Winfield A Tendon Transplant for Intrinsic Hand Muscle Paralysis, Surg Gynec. Obst 33 342, 1921.

Platt, Harry: The Pathogenesis and Treatment of Traumatic Neuritis of the Ulnar Nerve in the Post-Condylar Groove Brit. J Surg 13 409 1926.

— On the Peripheral Nerve Complications of Certain Fractures, J Bone & Joint Surg. 10 403 1928
—: The Operative Treatment of Traumatic Ulnar Neuritis at the Elbow Surg. Gynec. Obst. 47 822, 1928.
— On the Peripheral Nerve Complications of Fractures and Dislocations of the Elbow The Robert Jones Birthday Volume London 1928 Oxford University Press, p. 195.
Pollock L. J., and Davis L.: Peripheral Nerve Injuries, New York, 1933, Paul B. Hoeber Inc.
Richter C. P.: Instructions for Using Cutaneous Resistance Recorder or Dermometer on Peripheral Nerve Injuries, Sympathectomies and Paravertebral Block, J Neurosurg 3 181 1946.
Royle N D: An Operation for Paralysis of the Intrinsic Muscles of the Thumb, J A. M. A. 111 612, 1938.
Seddon, H. J The Use of Autogenous Grafts for the Repair of Large Gaps in Peripheral Nerves, Brit. J Surg 35 151 1947
Spurling R. G, Lyons, W R., Whitcomb, B B., and Woodhall, B: The Failure of Whole Fresh Homogenous Nerve Grafts in Man, J Neurosurg. 2 79, 1945.
Spurling R. G., and Woodhall, B: Experiences with Early Nerve Surgery in Peripheral Nerve Injuries, Ann. Surg. 123 731, 1946.
Steindler, Arthur Flexor Plasty of the Thumb in Thenar Paralysis, Surg Gynec. Obst. 50 1005, 1930
Stiles, Sir Harold J Operative Treatment of Nerve Injuries Am. J Orthop. Surg. 16 351, 1918
Stookey Byron: Surgical and Mechanical Treatment of Peripheral Nerves, Philadelphia, 1922, W B. Saunders Co.
Thompson, T C.: Orthopedic Measures for Use in Irreparable Nerve Injury J Internat. Coll. Surgeons 9 116, 1946.
Watson Jones, R.: Primary Nerve Lesions in Injuries of the Elbow and Wrist, J Bone & Joint Surg 12 121 1930
Whitcomb B. B.: Separation at Suture Sites as Cause of Failure in Regeneration of Peripheral Nerves, J Neurosurg 3 399 1946.
Whitman, Armitage: Congenital Elevation of Scapula and Paralysis of Serratus Magnus Muscle J A M. A. 99 1332, 1932.
Zachary R. B.: Tendon Transplantation for Radial Paralysis, Brit. J Surg 33 358 1946.

CHAPTER XII

AMPUTATIONS

By

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In the proper sense, amputation is the removal of an extremity through the continuity of the bone and should be distinguished from disarticulation which is resection through a joint For the purpose of simplicity both will be termed amputation in the general discussions which follow It is the surgical amputation, rather than the congenital, with which the present text is concerned

There are two main types of amputations open and closed. *The open type* is a temporary amputation for the control of actual or potential infection The surface of the wound is not covered with skin but is left open to facilitate drainage. This type must always be followed by a final surgical repair *The closed type* is a final amputation performed for the purpose of creating a stump which may be used effectively with a prosthesis.

The object of the surgical amputation is to save the life or preserve the health of an individual by severing from the body a harmful extremity to improve function by removing all or part of a deformed or useless limb and substituting for it an artificial member which will be more satisfactory from the functional standpoint and occasionally to remove an unsightly part for purely cosmetic reasons. Only one condition absolutely demands amputation regardless of all other circumstances, and that is a loss of blood supply of the extremity After nutrition is lost, the limb cannot survive being not only useless, but also a positive menace to life through the toxic products of tissue destruction which it will disseminate throughout the body it must be removed. In the presence of a harmful extremity one must first ascertain that such a procedure will completely eradicate the source of trouble. Specific indications for removal on this basis are (1) The presence of a malignant tumor which cannot be eliminated by other means, or which, as a necrotic, infected, fungating mass, is a menace to health. (2) The presence of an uncontrolled infection or one which profoundly affects the general health. In the presence of an awkward deformed or useless extremity the surgeon must use his judgment in determining that such a procedure is advisable in preference to orthopedic reconstruction. Specific indications for amputation under these conditions are (1) congenital deformity (2) tissue destruction from trauma or infection, which is so extensive that function is limited or completely lost and (3) the presence of a benign tumor whose removal would create a defect which would destroy function. If, under these circumstances, there is some hope of partial restoration of function by protracted reconstructive measures, it is well to take into account the patient s economic status and mental stability as well Frequently repeated surgery and prolonged hospitalization and convalescence will impose a financial

burden out of all proportion to the advantage gained, and all too often the treatment which must be carried out over a period of months or years will permanently affect the patient's mental balance. On the other hand amputation involves a mental hazard which some individuals are not able to surmount; in this event other orthopedic measures would be preferable. It behooves the surgeon to consider these psychological aspects and to prepare the patient mentally and emotionally for amputation for here readjustment after surgery is more difficult than that following any other orthopedic operation. If an open amputation is to be performed it is especially important that the patient realize this is a temporary measure and further surgery must follow. He should be told that the involved part alone is affected, that there are no hereditary effects, and that his family relationship will remain perfectly normal.

Much can be done in the way of occupational therapy to aid the amputee's rehabilitation, not the least of which is instruction in the use of an artificial limb. Though such appliances cannot functionally or aesthetically take the place of a lost extremity, those for the lower extremity and forearm are good substitutes, and can be comfortably fitted if the amputation stump is well planned and created by careful, thoughtful surgery.

All amputations may be divided into two groups: minor and major. Minor amputations are those carried out through the metatarsals or at any level distal thereto in the foot, and those performed through the metacarpals, or at any site distal thereto in the hand. At these levels an artificial limb will not be worn and the stump should be so planned that as much of its original function as possible may be retained or recreated. Following a minor amputation of the foot, the weight bearing surface should be capable of withstanding the trauma of stance and gait, and its shape should not cause discomfort by reason of bony prominences within the shoe. The hand, following minor amputation, should be so reconstructed as not to be aesthetically offensive, so that its investing skin will not break down under the pressure of grasp, and so its function will not be hampered by a painful scar.

Major amputations are those wherein a part or all of an extremity proximal to the metatarsals or the metacarpals is removed. Primarily they are designed for the use of an artificial limb. For this reason the surgeon must provide a stump which will be capable of activating a prosthesis and of withstanding the trauma of constant use year after year. Experience has shown that the stump at each level must conform to certain standards with regard to bone length, scar position, and general shape if the best results are to be obtained. Wound healing alone in a severed limb is not enough, and only too often a misconception on this point has led to the formation of stumps which are difficult or impossible to fit properly. So dependent is amputation surgery upon prosthetic requirements that a rudimentary knowledge of these appliances is necessary.

In the upper extremity the prosthesis and the stump bear no weight. The artificial arm is no substitute for the complicated neuromuscular functions of the normal arm but must be propelled in the desired position for gripping, lifting and pushing by the stump which acts as a lever arm. The artificial hand is of little functional value although the split hook mounted at the end of the

artificial limb provides a satisfactory grasp and hook action, its efficiency is also dependent upon the length of the stump and the power transmitted to it from the opposite shoulder or chest by means of a pull cord.

In the lower extremity the artificial limbs must carry the weight of the body in stance and gait These are of two types (1) those which bear the body weight on the bottom of the socket, thus bringing the pressure against the end of the stump, and (2) those which bear weight on the upper regions of the socket, causing the pressure to fall upon a bony support, such as the metaphyseal flare of the upper tibia or the ischial tuberosity in the thigh stump

It is readily apparent that the requirements of the amputation stump are dependent largely upon whether function is to be achieved with or without a prosthesis, and upon the level at which amputation is performed The ideal levels of amputation are those which have been proved most functional without a prosthesis in the case of the minor amputations and with a prosthesis in the case of the major ones.

LEVELS OF AMPUTATION IN THE UPPER EXTREMITY

The Fingers

In amputations through the fingers, it is essential that as much of their length, mobility and muscle strength as possible be retained. If a fingertip is lost the bone end must be covered with a well-cushioned, tactile pad, by means of a full thickness skin graft or flap a fingertip covered with thin or poorly nourished skin will heal by scar which will almost always be associated with pain tenderness, and tissue breakdown If amputation is carried out through the distal phalanx, the fingernails should be preserved if possible since they afford protection to the nail bed and facilitate the picking up of small objects, such as pins and coins. If amputation must be performed at a higher level in the fingers, the function of the affected digit and of the hand as a whole is the prime consideration. It should be remembered that the thumb being the chief participant in grasp and pinch, is the most important single digit. Of the fingers, the index and middle are the most important because of their strength, stability and relative proximity to the thumb The ring and little fingers, with their wide range of motion at the carpometacarpal articulations, provide the mobility of the metacarpal arch. Proximal to the distal phalanx the site of amputation must be chosen with the idea of providing a satisfactory covering of skin over the end of the stump Although interphalangeal disarticulation has often been viewed with disfavor it may be perfectly satisfactory when bulk and length are reduced through removal of articular cartilage to a point which prevents the stump from being unsightly, and from protruding beyond the neighboring fingers as they are flexed. In short stumps of the index and little fingers, removal at a higher level may be indicated when the remaining segment is awkward

The index finger occupies a unique position in the hand Because of its position, strength, and mobility in such varied actions as grip wide grasp (such as picking up a basketball), and pinch, wherein it is apposed to the thumb it is of greater functional importance than any other finger Here especially length should be conserved With even minor loss of length, the functions of the finger

are impaired If amputation is performed above the proximal interphalangeal joint, pinch and grasp are lost and only the stabilizing effect on the breadth of the hand remains. The middle finger substitutes for the shortened index finger in a measure, though the stump is then frequently in the way and subject to bruising In laborers, this is unimportant as grasp and hook are the principal functions of the hand breadth and stability of the palm however are important.

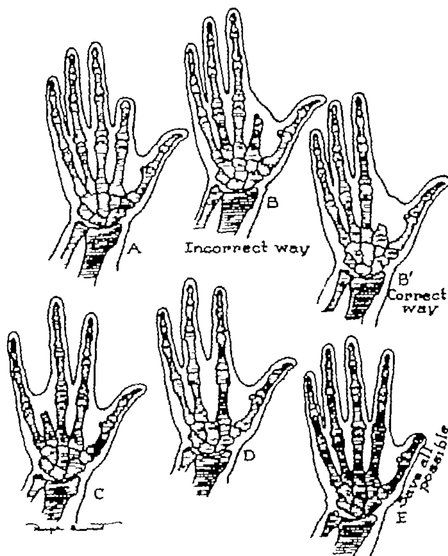


FIG. 555.—Amputations of hand. *A* Amputation proximal to middle finger joint of index finger eliminates pinch and hook. Increasing breadth of hand aids grasp but may form an impediment in web. *B* Amputation at this level of metacarpal presents obstacle in web and does not add to grasp because of instability accompanying loss of transverse metacarpal ligament. *B'* Correct method of amputation through index metacarpal. *C* Amputation proximal to third or fourth metacarpal head allows marked rotation of adjacent fingers. *D* Resection of third or fourth metacarpal with entire ray allows collapse of metacarpal head and prevents excessive rotation, although it narrows palm. *E* All possible length should be preserved in thumb. (From Slocum, D. B., and Pratt, D. R. J Bone & Joint Surg. 26: 535, 1944.)

For those whose occupation demands fine skill, the breadth of the palm is not a major consideration the maximum of agility and fine movement may be obtained by clearing the web space between the middle finger and thumb through amputation of the index finger at its base or disarticulation. The cosmetic result of this procedure is excellent. Amputation should never be performed distal to the base of the index metacarpal as the projecting end of the metacarpal bone is painful during grasp

Occasionally, both the index and middle fingers must be amputated through the metacarpals. In this event, the metacarpals should be resected at their bases to insure a satisfactory web between the remaining fingers and the thumb, and the suture line should be zig zagged to prevent secondary contracture. In amputation of the index, middle and ring fingers together the web space drops in a gradual arc from the fifth finger to the metacarpal head of the thumb Any protruding ends of bone in this arc should be resected

Amputation through the third or fourth metacarpal is seriously disabling The stabilizing effect of the transverse metacarpal ligament on the palmar arch being lost the neighboring fingers may rotate either toward or away from the amputated metacarpal during flexion, instead of pointing toward the tubercle of the navicular bone as they normally do. In this situation, excision of the entire metacarpal bone with collapse of the adjacent metacarpal heads, transplantation of an adjacent metacarpal bone to that of the amputated one, or a reconstructive bone graft is indicated.

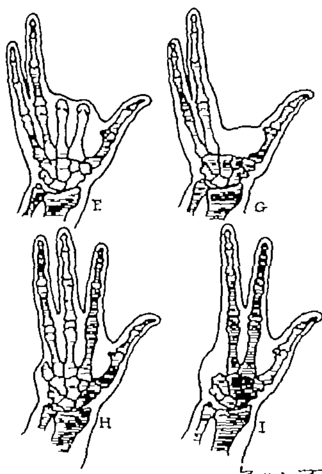


Fig. 456—Amputations of hand, continued. *F*, In amputations of index and middle fingers at or distal to proximal finger *joints, all* possible length should be saved to maintain breadth of palm for grasp. *G* In amputation of index and middle metacarpals proximal to their heads, section of bone should be carried out through metacarpal bases, thereby providing ideal web between thumb and *ring* finger Occasionally amputation will be necessary at level of carpometacarpal joint to effect *skin closure. H* In amputation of fifth metacarpal, preserve as much length as possible. *I* In amputation of 4th and 5th metacarpals, preserve maximum length. (From Slocum, D. B., and Pratt, D. R. J Bone & Joint Surg. 26: 535, 1944.)

On the ulnar side of the hand, if the fifth metacarpal alone is to be resected, its length should be preserved in so far as possible in order to better stabilize the palm of the hand and leave a base for the attachment of the adjacent in

trinsic muscles. If the cosmetic effect alone is considered, resection at a higher level will afford a smoother contour If the fourth and fifth metacarpals are amputated together the fifth should be left slightly shorter than the fourth to provide a more even contour

In amputation of the thumb especially, all possible length must be conserved The thumb should never be amputated if it can be preserved by orthopedic reconstruction An adequate covering may be provided by a skin graft or transplant. In performing plastic operations, anesthetic skin should not be allowed to remain in the tactile and pressure areas. Following amputation above the head of the proximal phalanx, function may be improved by deepening the web between the thumb and index finger to a point which permits effective consummation of the grasp Amputation proximal to the metacarpal head makes the hand useless save for hook or push action In rare cases, transplant of the index finger to the thumb may be indicated The reconstruction of a new thumb from a tube graft containing a piece of tibial bone is seldom desirable or successful.

Multiple amputation of all digits at the metacarpophalangeal joints results in a so-called 'mitten hand.' Such a hand serves only for pushing and for a limited amount of hook action afforded by flexion of the wrist. Here, phalangization may be accomplished by removal of the second and third metacarpals, together with the capitate bone, and by plastic closure of the defect. This creates a bifid stump which although unsightly, permits a limited amount of pincher action and is valuable in those cases where prehension is absolutely essential.

The Wrist

Disarticulation of the wrist and amputation through the carpus have two definite advantages over forearm amputation First there is no elbow joint in the prosthesis, such as is found in the one adaptable to the forearm, and no cuff above the elbow to limit flexion or to cause discomfort in the antecubital space Second, the arm retains pronation and supination, which materially facilitates the use of the prosthesis. To be satisfactory the stump must be covered with palmar skin, must have no protruding bony prominences, the radio-ulnar joint must be intact, and the vascularity and sensation of the stump must be unimpaired. If these criteria cannot be fulfilled, amputation should be performed at the ideal level in the forearm. The prosthesis for amputation at this level is difficult to fit. It consists of a molded leather cuff reinforced by a U-shaped steel and mounted by an attachment to receive the artificial hook or hand.

The Forearm

Amputations within the lower third of the forearm are usually unsatisfactory as the circulation is poor the underlying soft tissue is largely tendinous and fascial, and the skin is thin and poorly padded. Frequently, therefore, the stumps become cold, tender and cyanotic and thus are not readily adaptable to the prosthesis.

The ideal level for amputation in the forearm is the junction of the middle and lower thirds The end of the stump is smoothly tapered, and the scar is terminal Pronation and supination should be preserved in order to propel these movements in the newly developed forearm prostheses which contain a rotation

mechanism At this level the length of the stump is adequate for powerful activation of the artificial limb, and the cuff is sufficiently low to preclude impingement upon the anterior aspect of the elbow joint All possible length should be saved above this level, short forearm stumps are less effective in activating the prosthesis and are difficult to fit. Fortunately, improved fitting methods and the surgical excision of the distal one inch of the biceps tendon have made possible the fitting of stumps only one and one half inches in length

As to the prosthesis, the majority of existing commercial models consist of a rigid shell which fits directly over the amputated forearm and produces no pressure over the end of the stump The sides of the shell are mounted by steels which pass upward through elbow joints to be fixed to a cuff about the upper arm Distally they pass over the end of the socket where the hook or artificial hand is mounted

The Elbow

Disarticulation of the elbow is a poor operation in that the long, bulbous stump is difficult to fit with a prosthesis and allows no room for the mechanism of the artificial elbow unless the upper arm piece of the prosthesis extends below its normal level The advocates of amputation at this level point out the fact that the expanded distal end of the humerus affords a better grip for the socket of the artificial limb

Upper Arm

The supracondylar region is the ideal site for amputation above the elbow, since it may be fitted best with the standard prostheses Above this level the stump should be as long as possible. A stump which does not extend more than two inches below the axillary fold is of no functional use. Even above this level however, the length of the stump should be conserved in order that the contour of the shoulder may be maintained. The prosthesis for the arm amputated above the elbow consists of an upper arm piece and a forearm piece connected by an elbow joint which may be fixed in several positions The socket of the upper arm piece is a rigid cylinder, somewhat triangular in shape, extending to the axilla on the inside and several inches higher laterally, over the deltoid region. It is powered by a single control cord

Shoulder Disarticulation

Disarticulaion of the shoulder should be carried out only when removal of the head of the humerus is indicated.

Forequarter Amputation

Forequarter amputation is a mutilating procedure, and is performed solely for malignant growths. Prostheses are not practical at these levels, although a light shell is often worn in forequarter amputation to disguise the sloping contour of the thorax.

Amputations of the upper extremity tend to produce a deformity of the spine in proportion to the height of amputation The reasons for this are first, loss of the weight of the limb second atrophy of the muscles incident to loss of function and third the overdevelopment of the opposite limb Since the swing of the arm is lost, the normal rhythm of gait is also disturbed

LEVELS OF AMPUTATION IN THE LOWER EXTREMITY

The functions of the lower extremity stump and prosthesis are walking and static weight bearing The type of skin covering, the placement of the scar and the bony base of the weight-bearing area are chosen with consideration for these functions. The surgeon must try to simulate the ideal broad weight-bearing surface on the plantar aspect of the foot. As mentioned above, the lower extremity stumps bear weight either on the end of the stump on the metaphyseal flare of the tibia or on the ischial tuberosity depending upon the level at which amputation is carried out. In any case, the skin overlying the weight bearing surface should be capable of withstanding pressure. Rogers has pointed out that the only tissues which are normally subjected to pressure are (1) finely trabeculated cancellous bone surrounded by a thin cortex and covered by hyaline cartilage or adherent periosteum (2) tendinous origins or insertions of muscles and (3) the secretory pouches such as joints and bursa These must be covered by areolar tissue and skin of a congenitally specialized variety so arranged that the suture line and subsequent scar will fall well away from the pressure area. It is evident that the larger the weight bearing area, the wider the distribution of the load and the better the tolerance of the overlying skin. The bony base of the bearing surface must be broad and smooth, with rounded margins. These requirements limit the use of the end-bearing stump to the distal end of the femur the distal end of the tibia, and the calcaneus. The latter has certain prosthetic objections which restrict its use to the exceptional case

The Foot

In amputations of the forefoot length should be conserved, in so far as possible, to the bases of the metatarsal bones. Amputation of the great toe does not materially affect standing or walking at a normal pace. If the patient walks rapidly or runs, however a limp appears because of the loss of "take-off" from the great toe. Amputation of the second toe invariably is followed by a severe hallux valgus, from the tendency of this digit to drift toward the third in order to fill the gap left by amputation. Amputation of any of the other toes causes little disturbance Of these the fifth is most frequently removed the usual indication being overriding upon the fourth toe. Here, amputation may be performed with impunity and is usually preferred to reconstructive procedures because of its simplicity and finality Amputation of all toes causes little disturbance in ordinary slow walking but becomes manifest during more rapid gait and when spring and resilience of the foot is required. It also interferes with the actions of squatting and tiptoeing Usually no prosthesis is required at this level although the shoe may be stuffed at the points normally occupied by the toes.

Amputation through the metatarsal bones is disabling in proportion to the height of the amputation. The loss of "take-off" in the absence of a positive fulcrum in the ball of the foot is chiefly responsible for this impediment in gait. As a rule, patients use either a stuffed shoe with a spring steel band running longitudinally in the sole or simply a thick soled shoe. The prosthetic insole which some prefer is chiefly valuable in keeping the leather about the vamp of the shoe from rubbing on the dorsal skin.

Amputation at the tarsometatarsal joints (Lisfranc's amputation) is the highest which allows any function of the foot Even here, the awkwardness in walking, from the loss of support and push-off, is so disabling that amputation at a higher level may be required.

Amputation at the level of the mid tarsal joint (Chopart's amputation) has long been in disrepute because of the development of a severe equinovalgus deformity which is incompatible with walking and standing This arises from loss of the anterior supporting surface of the forefoot, and the unopposed action of the gastrocnemius-soleus muscle With the exception of those which incorporate arthrodesis of the calcaneus to the tibia, the remainder of the amputations through the tarsus are equally unsatisfactory

The Ankle

Amputations about the ankle joint must not only fulfill the requirements of an end bearing stump but leave adequate space between the end of the stump and the ground for the construction of the ankle joint mechanism of the artificial foot.

The Syme procedure meets these requirements better than any other amputation in this region The bone level is at the distal end of the tibia one fourth inch above the ankle joint and the tough durable skin of the heel flap provides normal weight bearing skin. When a Syme amputation is good, it is the most satisfactory functional level in the lower extremity though there apparently is no middle ground for evaluation. The stump is either *good* or *bad*, and if bad, the extremity must be amputated at a higher level. The principal objection to this level is its appearance. The prosthesis must pass around the flare of the distal tibial metaphysis, which is covered with heavy plantar skin, and thus is rather large and bulky For this reason, it is not recommended in women. The prosthesis itself consists of a molded leather socket with supporting steel on each side which passes to the bottom of the socket and is fixed to a foot piece. The bulbous end of the Syme stump provides sufficient fixation and no harness is required above the knee

The Boyd amputation is the method of choice when a prosthesis is not to be used This is carried out on the principle of talectomy forward shift of the calcaneus, and calcaneotibial arthrodesis. This procedure affords a little more length than the Syme amputation and a broader weight bearing surface. An elephant boot type of prosthesis, rather than the conventional type with a foot piece is used. Attempts have been made to fit these stumps with a conventional artificial limb The most successful results are obtained by the insertion of a wooden block beneath the socket of the artificial limb and increasing the break in the mid tarsal joint of the prosthetic foot until flexion is satisfactory The artificial foot is then similar to the human foot following arthrodesis of the ankle joint with compensatory motion in the mid tarsal joint.

Vasconcelos has described an amputation which involves an arthrodesis between the tibiotalar and tibiocalcaneal joint, with resection of the inferior portion of the calcaneus. The weight is borne on the heel pad through the arthrodesed segments.

The Pirogoff amputation involves arthrodesis between the calcaneus and tibia following the vertical section and removal of the anterior part of the

calcaneus. The heel flap is rotated forward and upward 90 degrees until the raw surface of the calcaneus meets the denuded distal end of the tibia. The two latter types of amputations have no advantage over the Boyd method, and technically are somewhat more difficult.

The Leg

The ideal amputation below the knee is carried out at a point six inches below the medial tibial condyle. The length of the bone may be varied between five and seven inches, depending upon whether the individual is tall or short. Stumps of this length afford an excellent lever arm, good skin, and adequate circulation. They also fit well in a prosthesis. Stumps extending into the lower third of the leg are poorly adapted to a prosthesis, and frequently break down because of poor circulation. In the prosthesis, the weight is carried on the flare of the upper end of the tibia. If the amputation stump is not ideal, a part of this weight may be transferred to the ischial tuberosity by extension of the thigh corset.

If the bone length of the below-knee amputation stump is less than five inches, it becomes progressively inefficient. In stumps shorter than three and one-half inches, the fibula, together with any additional muscle bulk, should always be removed, that the stump may fit better within the socket of the artificial limb. In short below-knee amputations (two to three inches of bone length) section of the medial hamstrings will allow the stump to fall within the socket for an additional inch or more.

If the short below-knee stump cannot be fitted satisfactorily by the conventional methods, the stump may be flexed to 90 degrees and fitted by a prosthesis which incorporates end-bearing. The prosthesis itself consists of a large molded leather cuff extending from the end of the stump to the upper part of the thigh with steels extending downward to hinge at the level of the knee joint and connecting the thigh corset with the hinge piece of the artificial limb. This is the modern equivalent of the peg leg prosthesis which has been used since the earliest times. This bent-knee stump is one of the most durable in the lower extremity and permits satisfactory walking.

Disarticulation of the Knee

Although the knee joint is not considered a favorable site for amputation, Rogers and Alldredge have demonstrated that it may occasionally give excellent results. To be satisfactory the skin cover must be excellent, and no undue bony prominence must remain. The artificial limb must be extremely well fitted, otherwise, a breakdown will ensue.

The Thigh

The end bearing amputation at the distal end of the femur is satisfactory if the end of the stump is covered by suitable weight bearing integument over lying a broad, smooth bony base. This level provides a long lever arm and a direct end bearing surface, and eliminates pressure from the prosthesis on the perineum. For these reasons, it is preferable to amputation at a higher level. Its only disadvantage is that the knee joint is somewhat bulky and the hinges

of the prosthesis do not incorporate friction to control the rapid swing of the shin during gait These amputations may be divided into two categories the tendoplastic, wherein weight is transmitted to the distal end of the femur through a layer of tendinous tissue, and the osteoplastic wherein pressure is transmitted through a bone (patella) which is arthrodesed to the distal end of the femur

The ischial bearing above the knee amputation should be at least four or five inches above the joint line of the knee This affords the minimum of clearance required in the fitting of the artificial joint and provides a lever arm measuring ten to twelve inches below the tip of the greater trochanter, depending upon the height of the individual Thus, the patient has excellent control of the stump in all directions. The adductor muscles of the hip which insert throughout the length of the femor shaft are sufficiently powerful to counterbalance the effect of the strong abductor In longer stumps the circulation is often poor and the skin overlying the end may rub against the knee block thus becoming bruised and abrased. This irritation can be avoided only by dropping the knee mechanism of the limb to a lower level, where it will protrude beyond the normal knee in the sitting position In shorter stumps, muscle balance is lost and control of the stump is less efficient An extremely short stump is difficult to contain within the socket of the prosthesis. It should be tailored as thin as possible since any redundant soft tissue will further complicate fitting Any thigh stump extending less than two inches below the perineum cannot be fitted

The Hip

Amputations about the hip are those wherein the limb is lost through the thigh above the level of the lesser trochanter The length of the bone should be conserved so far as possible The socket of the artificial limb which is shaped somewhat like a quarter hemisphere, is fitted with the remaining stump flexed to a right angle. The weight is thus carried on the ischial tuberosity If bone remains within the stump it will form a protrusion which is grasped by the contours of the socket, and will aid in retaining and controlling the limb A disarticulation which presents a smooth rather than an irregular contour is never indicated except for the removal of a tumor or disease process

Hindquarter disarticulation is carried out by division of the pelvis through the symphysis pubis anteriorly and through either the ilium or sacrum adjacent to the sacroiliac joint posteriorly A long posterolateral flap is used. Such a severe, shocking procedure is justified only in the presence of a malignancy and then only if one may reasonably expect to eradicate the disease The use of an artificial limb is seldom practicable although they have been constructed in a few cases, being similar in type to the tilting table prosthesis.

CLOSED AMPUTATION

The Principles of Amputation Technic.—The trend in amputation surgery within recent years has been toward simplification of technic and better shaping of the amputation stump to fit within the socket of the artificial limb Progress has been manifested in the application of sound surgical principles rather than in the development of new operations and technics. An appreciation of the importance of meticulous attention to detail and the gentle handling of tissues

is incumbent upon the surgeon who is actuated by the desire for perfection. The following suggestions will serve as a guide to the principles of final amputation

1 A clean operative field is essential. The skin must be free of foreign material, crusts, and blemishes. If a fresh open wound is to be closed, the requirements for closure of wounds in general must be fulfilled, namely every effort must be made to prevent contamination and destruction of tissue Old open wounds must present a clean, firm, cherry red granulating surface The latter are usually prepared by debridement and elimination of all deep infections, followed by dakinization, whirlpool baths, and saline packs. These open granulating surfaces need not be covered with temporary skin grafts. Throughout the operation itself, a strict aseptic technic must be followed.

2. A tourniquet is applied routinely, except in peripheral vascular disease. This insures a clean operative field and minimizes blood loss. Prior to the application of the tourniquet, an elastic bandage may be used to express the blood from the extremity, provided spread of infection or a malignant growth will not be affected by its use.

3 The most important feature of amputation is the provision of a good skin covering over the end of the stump The skin must have normal sensation and mobility and an adequate amount of subcutaneous fat. The healed surgical scar should be flat thin and nonadherent. It should always be placed where least subject to pressure or tension. Skin flaps should be sewn under normal tension tight flaps tend to break down because of avascularity and tension while loose redundant folds of skin fit poorly in a prosthesis. The flaps should be cut so that their combined length is equal to the diameter of the limb at the point of amputation The incision should start at the bone level or slightly above it. The following general rules regarding the length of the flap may be laid down

a In the upper extremity all amputations above the level of the wrist should be performed with anterior and posterior flaps of equal length. This allows the operative scar to fall in the terminal position, where it will not be affected by pressure from the prosthesis on the sides of the stump In amputations distal to the wrist, a long anterior and short posterior flap should be provided in order that the thick tough palmar skin may be utilized as a covering for the end of the stump

b Amputations about the hip are performed through racquet incisions so placed that the scar falls to the anterior or lateral aspects of the stump This keeps the scar well away from the weight bearing ischial tuberosity and reduces the danger of fecal contamination in the immediate postoperative period.

c In thigh amputation, the length of the flaps will vary according to the technic employed. Flaps of equal length are used by those who prefer the position of the scar immediately behind the bone end, while others prefer an anterior flap one inch longer than the posterior that the scar may be one inch above the bone end I prefer the latter method.

d. The end bearing amputations of the distal end of the femur necessitate a long anterior or short posterior flap so the suture line may lie posteriorly and immediately above the weight-bearing end of the stump

e In the below the-knee amputations, anterior and posterior flaps of equal length allow the scar to lie transversely immediately behind the tibia. The

anterior flap should be about one half inch longer than the posterior, adhesions to the bone end are better avoided by this slight additional length All scars on the sides of the stump should be avoided whenever possible

f In the Syme amputation, a long posterior heel flap is used in order to place the scar anteriorly above the weight bearing area. It should be emphasized that the foregoing flap lengths and suture line positions, although ideal, should not be employed at the sacrifice of valuable bone length A plastic rearrangement of the skin will usually permit closure in a manner which will reduce the effect of pressure to a minimum degree

4 The muscles are divided just distal to the saw line in order that after retraction they will remain at this level When a flap of tendon or muscle is to be cut in the same configuration as a skin flap, no effort is made to separate the two Examples of this are found in the tendoplastic amputations about the knee, and the large deltoid flap in amputations about the shoulder Fascial flaps are valuable in grouping the cut muscles about the sides of the bone Large bulky muscle masses should never be placed over the bone end.

5 The periosteum is divided by sharp dissection at the bone level No attempt is made to remove a one-fourth inch periosteal cuff above that site. The bone is divided transversely to its longitudinal axis in all but the end bearing amputations. In the latter the bone is divided so the end lies parallel to the ground if the patient is assumed to be in the standing position Following division of the bone all sharp or projecting bony prominences should be removed, and the end smoothed with a file Finally bone dust is irrigated from the wound with normal saline

6 Nerves are isolated pulled down gently, and sectioned cleanly with a knife, then allowed to retract above the end of the bone. Strong tugging and pulling upon the nerves are strictly avoided Painful neuromata and phantom pain in the limb are less likely when the nerves are treated in this manner than when they are injected or closed by a special plastic technic, or when the ends are buried within the bone.

7 The major vessels are isolated and doubly ligated with plain catgut, and the minor vessels are ligated with a single strand of fine catgut. Thereafter the tourniquet is removed, and hemostasis completed.

8 The skin flaps are approximated with interrupted skin sutures. No tension sutures are used otherwise ischemia of the skin near the suture line may follow

9 Following operation, a drain should be placed in the wound when muscle has been extensively cross-sectioned to minimize the formation of hematoma. The wound is now covered with a dry dressing and the latter is held in position by an elastic compression bandage wrapped over sheet wadding to distribute the pressure. Bony prominences, such as the crest of the tibia are always padded well to prevent localized sloughing of the skin from pressure Smooth even compression serves to minimize the postoperative edema, eliminate dead space and mold the stump The patient is placed at absolute bed rest with the limb elevated until healing takes place Plaster splints are used in below knee amputations to insure tissue rest and prevent flexion contractures of the knee The dressings are removed after forty-eight to seventy two hours, and the drain is withdrawn The wound is not again disturbed until the twelfth or fourteenth

day at that time the skin sutures are removed If the wound is well healed stump and general body exercises are instituted to prepare the patient for the artificial limb Elastic bandaging of the stump is continued until maximum shrinkage has taken place An artificial limb is fitted when the stump is free from edema pain and tenderness, and the skin is soft and pliable This requires a minimum of eight to twelve weeks

TECHNICS OF CLOSED AMPUTATION

Fingertip Amputations

The sliding flap maintains sensation and is thus preferable to free skin grafts for covering

The involved finger or fingers should be thoroughly cleansed, including the *area from which the sliding flap is to be taken. The wound is then debrided,* all loose skin tags being severed and the bone being smoothed and leveled to the surface of the wound The skin flap is transferred to the denuded area and fixed with several fine interrupted sutures. If a sliding flap cannot be used the free full thickness graft is the preferred alternate, in that sensation is frequently re-established within the graft, and it provides far better padding than the *split thickness type The free graft is more desirable than the flap graft which* originates usually from the thenar eminence or the abdomen if the finger is tied to the donor site, the patient may inadvertently pull the digit away with a disastrous result.

Amputation Through the Finger

Removal of a portion of the finger distal to the upper portion of the proximal phalanx is carried out through a long palmar and a short dorsal incision. Above that level a short dorsal racquet incision is used.

Amputation of the Fingers Distal to the Proximal Portion of the Proximal Phalanx in the Clean Field—The incision is begun at the bone level. The *palmar flap should be equal in length to the transverse diameter of the finger* while the dorsal flap is approximately half this length This prevents undue tension at the scar line, and a consequent breakdown of the wound or limitation of motion after healing If 'dog ears' are present at the lateral borders of the *suture line at the time of closure, they may be removed by V plastic incision* The finger is held in extension when the palmar flap is cut, and flexion when the dorsal flap is cut. The extensor tendons are next sectioned to retract to the bone level. The flexor tendons are sectioned to retract above the level of the transverse carpal ligament of the wrist to prevent adhesions to adjacent tendons. Section is accomplished while the wrist and finger are held in acute flexion and strong traction is applied to the tendon The distal phalanx is extended by intrinsic muscles and flexed by the flexor profundus, the middle phalanx is extended by the intrinsic muscles and flexed by the flexor sublimis and the proximal phalanx is extended by the common extensors and flexed by the lumbricales. Thus, each section of the finger has its own motor supply, and suture of the tendons over the stump end is unnecessary in fact, this is poor policy in that flexion or extension contracture may *follow* The bone is next sectioned at the desired level, preferably with a saw *the nutcracker action of*

a rongeur or bone biting forceps will frequently produce a fracture The significant digital nerves which lie at each side of the finger are isolated, drawn down sectioned, then tucked upward within the nerve bed The skin flaps are approximated and fixed with interrupted sutures

Amputation Through the Proximal Portion of the Proximal Phalanx.—A short, dorsal racquet incision is employed beginning at the level of the joint line and proceeding downward to swing around the finger at the level of the proximal flexor crease and joins the dorsal incision The extensor tendon is sectioned the flexor tendons are drawn strongly downward and sectioned to fall above the transverse carpal ligament and the nerves are isolated sectioned and tucked up within the lumbrical canal away from the end of the wound Following bone section the racquet incision is closed by interrupted suture

Disarticulation of the Fingers—When disarticulation rather than amputation through the continuity of the bone is performed the technic is essentially the same, except for the bone section Here the capsule is divided first over the dorsum while the finger is held in acute flexion The line of capsular incision then follows circumferentially around the joint Removal of the articular cartilage from the end of the phalanx is usually desirable to insure better healing and to reduce the size of the stump

Amputation in the Freshly Injured Hand.—In the freshly injured hand the technic is somewhat different The skin flaps are fashioned according to their availability The tendons are sectioned so as to prevent retraction above the level of the wound and ascending infection in the tendon sheaths

AMPUTATION THROUGH THE METACARPAL BONE

Amputation through the metacarpal bone is performed through a long dorsal, racquet incision beginning at the base of the bone and continuing downward and around the base of the finger at the level of the proximal flexor crease. When the index metacarpal is to be sectioned the queue or longitudinal portion of the incision passes along the ulnar side of the bone To expose the third and fourth metacarpals, the incision is placed over the mid portion of these bones. The approach to the fifth metacarpal passes along its radial side The extensor tendon to the involved finger is then cut The metacarpal bone is sectioned extraperiosteally at the desired level and removed. The incision is deepened to the flexor tendon the latter is drawn down, and with the wrist in flexion is sectioned so it will retract above the transverse carpal ligament The remaining soft tissues are collapsed into the defect created and the metacarpal heads of the two adjacent fingers are approximated and fixed with a catgut suture In the middle and ring fingers, the defect created may be filled by transplantation of the adjacent index or ring finger with its metacarpal or the defect may be filled by a bone graft from the fifth metatarsal bone of the foot If the latter method is used the entire metacarpal shaft is not removed.

AMPUTATION THROUGH THE CARPUS

In amputation through the carpus a long palmar and a short, dorsal flap in the ratio of 2 1 is necessary The skin flap is dissected upward to expose the soft tissues to the proper bone level The extensors and flexors of the fingers

are drawn down and sectioned so they will retract upward into the forearm while the flexors and extensors of the wrist are reflected upward above the bone level and later reattached to the end of the bone at the most distal convenient point in line with their normal insertions. The large median and ulnar nerves and the fine filaments of the radial nerve are drawn downward and sectioned to retract above the carpus Division of soft tissues to the bone level is now completed. The bone is then divided with a saw and fashioned to form a smooth rounded contour with no projecting bony eminences. Under normal tension, the skin flaps are approximated over the bone end by interrupted sutures.

DISARTICULATION OF THE WRIST

The skin incision is begun at a level one-half inch below the styloid processes, and is carried down over the palm and dorsum of the hand to form a long anterior flap of palmar skin and a short dorsal flap These flaps are reflected upward to expose the radiocarpal joint. The radial and ulnar arteries are identified, sectioned, and doubly ligated. The median, ulnar and radial nerves are drawn down gently and sectioned so as to fall above the level of the wrist joint. The remainder of the soft tissues are divided starting at the radial side of the wrist and progressing toward the ulna until the wrist and hand are freed. The cartilage overlying the end of the radius and the radio-ulnar joint are not disturbed. The prominences of the styloid processes may be removed if they project unduly The skin flaps are approximated by interrupted sutures.

AMPUTATION THROUGH THE FOREARM

At the Ideal Level.—The forearm is placed upon an arm board by the side of the operating table, in a position midway between supination and pronation. Anterior and posterior skin flaps of equal length are cut beginning at the bone level The underlying muscle fascia is exposed, cut in a pattern similar to the skin flap, and reflected upward The radial, ulnar and median nerves are identified and sectioned to fall above the bone level. The muscles are sectioned transversely to fall at the intended bone level The two fascial flaps are now approximated with fine catgut sutures, and the wound is closed by approximating the two equal skin flaps with interrupted suture

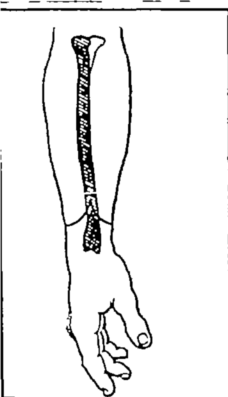
Some surgeons prefer not to use formal fascial flaps, simply sectioning the fascia and muscle immediately distal to the bone end following its division. Still others prefer to cover the bone end by muscle and fascia. This is done by the use of a long anterior flap consisting of the flexor sublimis and its investing fascia The remainder of the soft tissues are divided transversely at the bone level. Following bone section, the muscle flap is sutured to the dorsal muscle fascia. *Because of the excessive bulk, the entire anterior muscle mass should never be placed over the end of the bone.* The periosteum is now sectioned in a circular dissection, and the bone divided immediately below the periosteal incision The median, ulnar and radial nerves are isolated, drawn down gently and sectioned at a point which will permit them to fall above the bone end. The major vessels are carefully isolated and ligated The skin is approximated with skin sutures under normal skin tension.

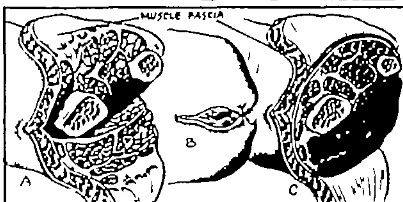
Through the Upper Third of the Forearm.—An anterior and posterior skin flap is preferred if this is not convenient, however any available skin may be

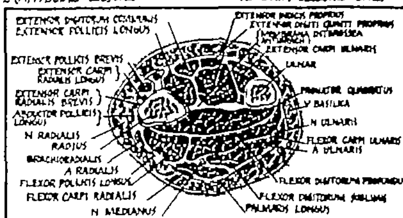
utilized A fascial flap from the investing muscle fascia of sufficient length to cover the end of the stump, is desirable The bones are sectioned transversely in the usual manner All excess muscle bulk is removed by careful trimming so that the stump will taper after closure If the end of the stump is not one and one half inches below the insertion of the biceps tendon it cannot be retained in a prosthesis Under these circumstances, the distal one inch of the biceps tendon is resected as advised by Blair and Morris

AMPUTATION THROUGH THE HUMERUS

Through the Supracondylar Area.—Anterior and posterior flaps of equal length are employed starting at the point where the shaft of the humerus begins to merge into the humeral condyles The muscles in the anterior aspect of the arm are sectioned one half inch distal to the saw line to retract to this point after







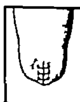


Fig 557 —Amputation through forearm at ideal level.

being divided. The flat expansion of the triceps tendon is cut at the level of the insertion of the olecranon The soft tissues are reflected upward the periosteum is incised circumferentially just proximal to the intended bone level and the bone is divided transversely The brachial artery is isolated and doubly ligated and the median ulnar and radial nerves are sectioned to fall above the bone end. The triceps tendon is brought forward and sutured to the brachialis and biceps. Skin flaps are approximated with interrupted sutures.

Between the Supracondylar Area and the Surgical Neck.—Anterior and posterior flaps of equal length are formed beginning at the intended bone level. The flaps may be modified in any manner necessary to effect a plastic closure, if it will afford additional length. The anterior muscles are sectioned to fall at the level of the bone. Here the biceps muscle will contract more than the other muscles, and thus must be cut at a lower level. Posteriorly the triceps and its overlying fascia are sectioned about one and one half inches below the bone level, and beveled to form a thin myofascial flap. If the triceps is not available muscle fascia alone may be used. The nerves are isolated and sectioned to retract above the end of the stump. The major vessels are occluded by double ligature. The skin is then approximated by interrupted sutures.

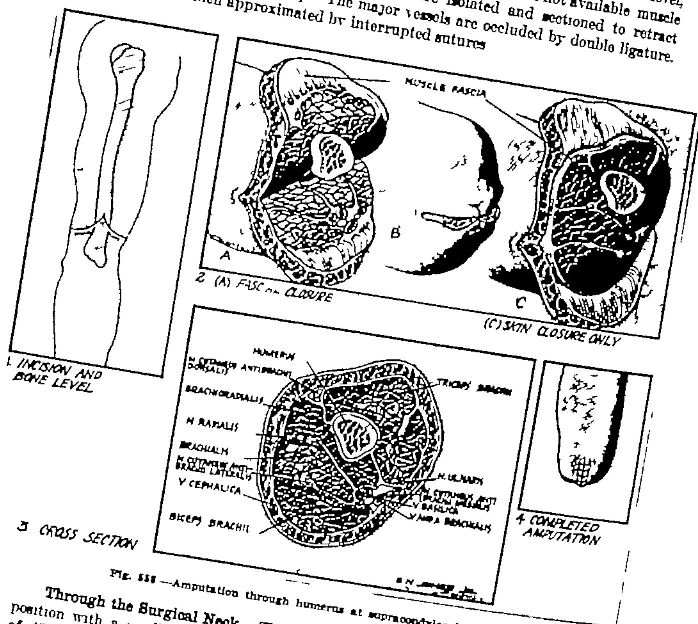


Fig. 558—Amputation through humerus at supracondylar level.

Through the Surgical Neck.—The patient is placed in the dorsal decubitus position with a sandbag well beneath the shoulder so the back is at an angle of 45 degrees with the table. The skin incision is begun at the level of the coracoid process continued along the anterior border of the deltoid muscle downward to its insertion thence along the posterior aspect of the deltoid to the axillary fold. The two ends of the incision are connected by a second incision

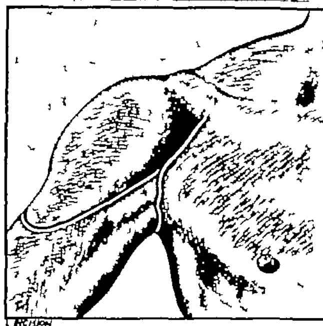
passing through the axilla The pectoralis major muscle is sectioned at its insertion and reflected medially The interval between the pectoralis minor and coracobrachialis muscle is developed to expose the neurovascular bundle The axillary artery and vein are sectioned immediately below the pectoralis minor muscle The median, ulnar, radial, and subcutaneous nerves are next isolated drawn down, and sectioned so that they fall above the pectoralis minor muscle The deltoid muscle is then sectioned at its insertion and reflected upward together with its attached lateral skin flap the teres major and latissimus dorsi muscles are sectioned near their insertions at the bicipital groove, and the humerus biceps, triceps and coracobrachialis are cut at a point three-fourths of an inch distal to the saw line The bone is now transected at the level of the humeral neck The long head of the biceps and coracobrachialis is sutured over the cut end of the humerus while the pectoralis major is swung laterally and sutured to the inferior pole of the bone to be covered by the deltoid muscle. The skin flap with its underlying deltoid muscle is now tailored to accurate approximation, and fixed with interrupted skin sutures

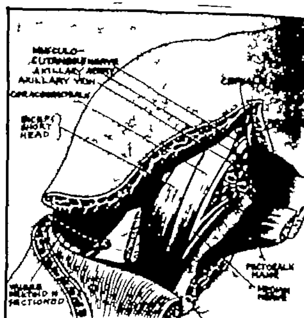
DISARTICULATION OF THE SHOULDER

The patient is placed in the dorsal decubitus position with a sandbag under the shoulder so the back is at a 45 degree angle to the table The skin incision follows the deltoid border from the coracoid process downward to its insertion thence upward to the axillary fold A second incision joins the two ends of the first incision at the level of the axillary fold The interval between the coracobrachialis and the short head of the biceps is deepened to expose the neurovascular bundle The axillary artery and vein are sectioned and doubly ligated as is the thoracoacromial artery if found within the field. The vessels are allowed to retract upward beneath the pectoralis minor The median, ulnar and musculocutaneous nerves are then drawn down gently injected with Novocain, and sectioned so they will fall at the same level The coracobrachialis and short head of the biceps are next sectioned near their coracoid insertion and the deltoid muscle is detached from its insertion on the humerus and reflected upward to expose the capsule of the shoulder joint The arm is now placed in internal rotation for section of the short rotator muscles and the posterior capsule then in extreme external rotation for incision of the anterior aspect of the capsule The teres major and triceps muscles are sectioned near their insertions, and the inferior capsule is divided to complete the severance of the limb All cut ends of the muscle are now reflected into the glenoid cavity and sutured in this position The deltoid flap is brought downward and fixed just below the glenoid with several interrupted sutures The skin is trimmed for accurate approximation, and the wound closed with interrupted sutures A drain may be placed in the posterior inferior angle of the wound (Fig 559)

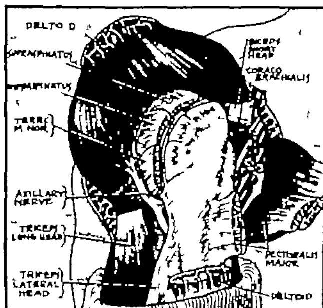
FOREQUARTER AMPUTATION

The incision starts at the lateral border of the sternocleidomastoid muscle follows the anterior aspect of the clavicle over the acromioclavicular joint, passes over the top of the shoulder to the spine of the scapula, and thence along its vertebral border to its angle. The lower limb of the incision begins in the middle third of the clavicle passes downward in the groove between the deltoid

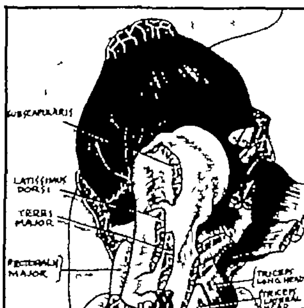

1 INCISION



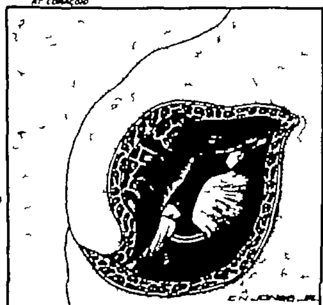
2 EXPOSURE AND SECTION OF NEURO-VASCULAR BUNDLE



3 (A) REFLECTION OF DELTOID (B) THE ARM IS PLACED IN INTERNAL ROTATION (C) SECTION OF SUPRASPINATUS, INFRASPINATUS, TERES MINOR AND POSTERIOR CAPSULE (D) SECTION OF CORACO-BRACHIALIS AND BICEPS AT CORACOID



4 ARM PLACED IN EXTERNAL ROTATION THE SUBSCAPULARIS AND ANTERIOR CAPSULE SECTIONED


5 SUTURE OF MUSCLES IN GLENOID CAVITY

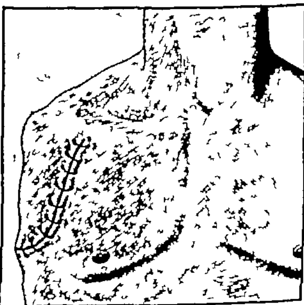
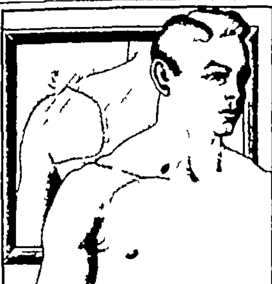
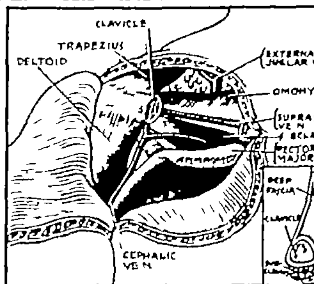

6 COMPLETED AMPUTATION

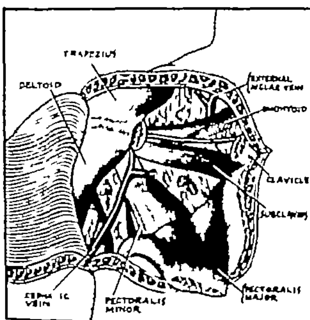
Fig. 559 —Disarticulation of shoulder



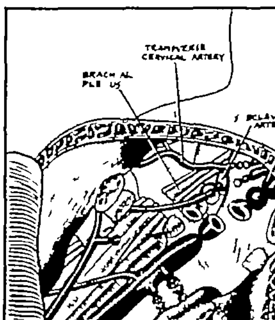
1 INCISION



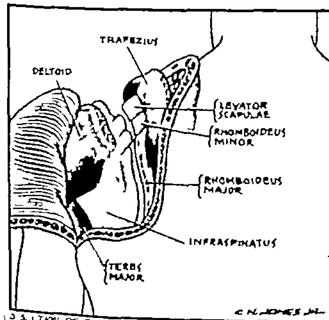
2 RESECTION OF CLAVICLE



3 LIFTING THE PECTORAL LID



4 SECTION OF VESSELS AND NERVES AFTER INCISION AXILLARY FASCIA, INSERTION OF PECTORALIS MINOR, CO MEMBRANE AND SUBCLAVIUS



5 SECTION OF THE SUPPORTING MUSCLES OF THE SCAPULA



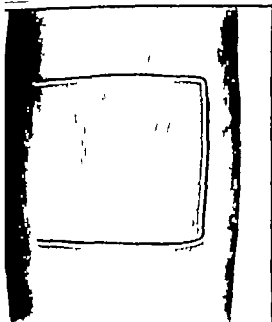
6 COMPLETED AMPUTATION

and pectoral muscles, to cross the axilla and join the upper incision at the angle of the scapula. The clavicular limb of the incision is now deepened to bone. The pectoralis major is resected from its clavicular origin and turned downward. The deep fascia overlying the upper border of the clavicle is divided close to the bone. The deep aspect of the clavicle is next freed by finger dissection and the use of a blunt curved dissector The external jugular vein is retracted from the field, or, if in the way is sectioned. The bone is then divided at the outer border of the sternocleidomastoid muscle by means of a Gigli saw The clavicle is lifted upward and removed by division of the acromioclavicular joint. The pectoralis major muscle is cut at its humeral insertion and the pectoralis minor at the coracoid to complete the exposure of the neurovascular bundle. The subclavian artery and vein are isolated and doubly ligated, and the brachial plexus is injected with Novocain and sectioned and allowed to retract upward. The latissimus dorsi and remaining soft tissues binding the shoulder girdle to the anterior chest wall are next sectioned to allow the limb to fall freely backward. The arm is now placed across the chest and held with gentle downward traction, while the remaining muscles fixing the shoulder to the scapula are divided as they are encountered, from above downward The muscles still holding the scapula to the thorax are divided, starting with the trapezius muscle and continuing through the omohyoid levator anguli scapuli rhomboideus major and minor and serratus magnus. The extremity then falls free to be removed. To form additional padding the pectoralis major trapezius, and any other remaining muscular structures are sutured over the lateral chest wall Flaps are brought together retrimmed and approximated with skin sutures A drain is inserted into the wound and allowed to remain for forty-eight to seventy two hours. Dry dressings are applied.

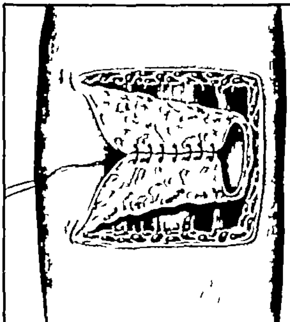
CINEPLASTIC AMPUTATION

A cineplastic amputation is one in which the stump is so formed that the patient may activate the prosthesis by a muscle motor within the muscles of the stump itself rather than by remote control from the opposite shoulder or thorax The so-called motor is composed of (1) an inverted tube flap which has been drawn transversely through a muscle canal and affixed to the skin on the other side and (2) an ivory peg which is placed within the tube to transmit muscle power to the prosthesis by means of pull cords fastened to each side, thereby regulating the mechanism of the artificial hand. Although many types of cineplastic amputations have been devised, only those wherein the motor is placed within the muscle belly have proved satisfactory This limits the location of the motors to the middle third of the anterior and posterior aspects of the arm or forearm or to the pectoral region The surgical procedure necessary to form the motor is occasionally performed at the time of the final type amputation, though the writer feels that in order to avoid possible circulatory disturbance in the integument of the stump end, it is best carried out as a second stage after the wound has healed. On the same basis, only one motor should be placed on an arm or forearm stump at one operation Before operation is undertaken the surgeon should be sure the stump is long enough to provide adequate excursion

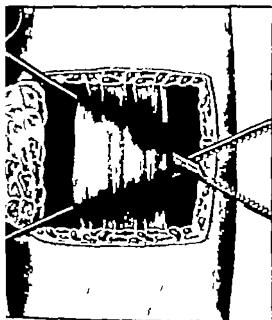
Fig 561 —Cineplastic amputation, whereby stump is so formed that patient may activate prosthesis by a muscle motor within muscles of stump, rather than by remote control from opposite shoulder



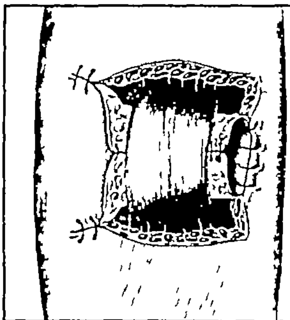
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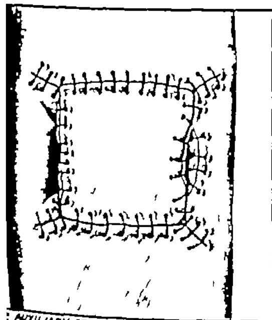
2 TUBE FORMATION



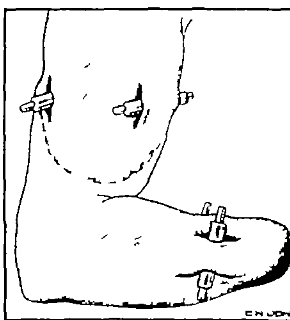
MUSCLE CANAL



4 TUBE PASSED THRU THE CANAL AND SUTURED



AUXILIARY SPLIT SKIN GRAFT



6 COMPLETED AMPUTATION ABOVE AND BELOW ELBOW WITH PEGS IN PLACE

of the muscle, that the muscle is sound, and that the overlying skin is normal and healthy Further he should determine the course and location of the muscles to be utilized.

Technic.—A square skin flap is created on both the anterior and posterior aspects of the forearm or arm (If in the pectoral region, only one flap is formed, over the pectoralis major) The three cut edges of the flap and its attached base should be of equal length, each measuring not less than two inches. The incision is carried to the deep fascia and reflected backward over its base. The two free corners of the flap are approximated by a silk suture, permitting the subcutaneous fat to lie on the outside of the tube to be formed. A second suture is placed near the base of the flap Tension is now exerted upon the silk sutures at each end of the tube, and the edges of the flap thus approximated are fixed by No 000 plain catgut subcuticular sutures Nonabsorbable sutures are not desirable being difficult to remove after the tube is placed in the muscle canal The muscle is grasped by the thumb and index finger and pierced transversely to form a tunnel or canal. By finger dissection or by the use of a special conical dilator the canal is expanded until one and one-fourth inches in diameter The tube is then inserted into the canal and its unattached end is fixed to the skin on the other side of the defect by interrupted silk sutures. The angles at each end of the base of the flap are closed by several sutures, while the remaining defect is closed by the application of a split thickness free skin graft. The completed tube should be large enough to admit the little finger A dry petrolatum jelly gauze and a dry dressing are applied. A plaster splint is preferably used to immobilize the extremity during the healing period. The stitches are removed between the eighth and twelfth day After healing is complete, a peg is passed through the canal and exercises are instituted to strengthen the muscles and condition the skin of the canal to the peg

THE LOWER EXTREMITY

AMPUTATION THROUGH THE TOES

A long plantar and short dorsal skin flap are formed. The incision is begun at the intended bone level on the mid point of the medial side of the toe, and curved over the dorsal aspect, to end at a similar point on the lateral aspect. The plantar flap is slightly longer than the dorsoplantar diameter of the toe at the bone level, and is composed entirely of plantar skin. The skin flaps are dissected upward to the saw line. The flexor and extensor tendons are now sectioned and allowed to retract. The digital nerves are isolated, and sectioned to fall just above the bone end. A circumferential periosteal incision is then made the bone divided immediately below it, and the toe removed The digital blood vessels are sectioned and tied with No 000 catgut. A test fit of the skin flap is next made, and the excess tissue trimmed away The wound is closed with interrupted sutures.

AMPUTATION AT THE BASE OF THE PROXIMAL PHALANX

The skin incision varies with the toe involved. In the great toe, a single long posterior-medial flap is formed. Beginning at the base of the dorsal aspect of the toe in the midline the incision is curved distally over the medial

and posterior medial aspects a distance slightly greater than the anteroposterior diameter of the digit. Thence, it courses proximally across the plantar surface to the web space Upon closure, this flap is reflected laterally and sutured to the medial edge of the skin in the web space In the second, third, and fourth toes, amputation is performed through a short, dorsal, racquet incision The queue of the incision starts one centimeter above the metatarsophalangeal joint and passes downward to the level of the base of the proximal phalanx, where it divides to pass around the toe and cross the plantar surface at the level of the flexor crease. Following removal of the toe, this wound is closed by side-to-side approximation In the fifth toe, a long lateral flap is formed, of sufficient length to cover the defect left by removal of the toe Closure is effected by medial approximation of the flap to the skin in the web space. In each instance, after the incision is made, the flaps are reflected upward to the bone level In the great toe, the tendons are sectioned, and the flexor and extensor tendons approximated to maintain the position of the sesamoid bones underlying the head of the first metatarsal In the remainder of the toes, the tendons are simply drawn down, sectioned, and allowed to retract. The nerves are then identified and sectioned above the bone end, and the major blood vessels are ligated. The bone is sectioned at the desired level and the wound is closed by interrupted skin sutures.

DISARTICULATION AT THE METATARSOPHALANGEAL JOINT

Disarticulation of this joint is performed in the same manner as amputation through the base of the proximal phalanx, differing only in the level of the bone and the manner of its resection The capsule of the metatarsophalangeal joint is identified with the toe in acute flexion, its dorsal side is sectioned first the toe is then straightened and the remainder of the capsule is exposed and incised.

AMPUTATION OF A SINGLE METATARSAL

A dorsal, racquet incision is begun at the anticipated bone level, passed downward over the metatarsal shaft, thence through the web space across the flexor crease of the toes, and upward to join the point of origin The soft tissues are divided to the bone. The tendons are pulled down and severed so as to retract above the bone level The nerves are next divided in a manner to conserve sensation in the adjacent toes. The bone is then divided, bleeding controlled and the skin approximated with interrupted sutures.

TRANSMETATARSAL AMPUTATION

A long plantar and short, dorsal flap are used. The dorsal incision is begun at the level of the saw line on the anteromedial aspect and curved slightly below the level of intended section, to reach the mid point of the lateral side of the foot The plantar incision is begun at a similar point and carried downward below the metatarsal heads. Because of the greater cross-sectional diameter to be covered with skin the incision is slightly longer on the medial than on the lateral side. Further the plantar flap should include the subcutaneous fat and a thin beveled layer of plantar muscles. After the flap is reflected upward to the saw line, the metatarsals are sectioned transversely the nerves are

sectioned to fall above the level of the bone and the tendons are divided and allowed to retract. The long plantar flap is now over the wound and is approximated to the dorsal flap. To prevent drop-foot, a posterior plaster splint is advisable following operation.

OBSOLETE AMPUTATIONS THROUGH THE FOOT

These operations include tarsometatarsal disarticulation, which has been discarded because of the equinus deformity which usually develops; the Chopart's amputation, which is followed by a severe equinovalgus deformity; and the Pirogoff amputation wherein the calcaneus is rotated forward to be fused to the tibia after vertical section in its mid portion.

SYME AMPUTATION

In the Syme amputation, a single, long posterior heel flap is utilized. Beginning at the most distal tip of the lateral malleolus, the incision passes across the front of the ankle joint at the level of the distal end of the tibia to a point one fingerbreadth below the tip of the medial malleolus. It then passes vertically downward at right angles to the bottom of the foot and crosses the sole to the lateral aspect, ending at the starting point. All structures are divided to the bone. The tarsus is next excised: the foot is placed in strong plantar flexion, and the anterior capsule of the ankle joint divided. The supporting ligaments on each side of the ankle are divided by inserting a knife in the joint space between the malleoli and talus, and drawing the knife downward to section first the deltoid ligament on the medial side, and then the calcaneofibular ligament on the lateral side. To provide further equinus, a bone hook is now placed in the posterior aspect of the talus, and dissection proceeds posteriorly through division of the posterior capsule of the ankle joint. Dissection is carried back close to the bone along the superior surface of the calcaneus to the insertion of the tendo Achilles. The tendon is divided at its insertion in the posterior aspect of the calcaneus. The bone hook is now placed in the posterior aspect of the heel and the calcaneus is pulled into still further plantar flexion, as dissection continues on the undersurface of the calcaneus until the distal end of the plantar skin flap is reached. The entire foot, with the exception of the heel flap, is removed. The heel flap is retracted backward and the soft tissue dissected away from the tibia and malleoli. The periosteum is incised circumferentially one-fourth inch above the joint line, and the bone is divided at this level so that the cut surface will be parallel to the ground if the patient is in a standing position. All sharp corners of the bone end are now rounded and smoothed. All visible tendons are then pulled down and sectioned to fall above the bone level. The medial and lateral plantar nerves are next dissected upward and divided above the bone end. The posterior tibial artery and vein are isolated and ligated just above the cut distal edge of the heel flap while the anterior tibial artery is ligated as it lies in the anterior flap. The heel flap is debrided of all remaining muscle and fascia, any excess subcutaneous fat is removed, and the flap is approximated to the anterior flap with interrupted sutures. Large, protruding tags of skin (dog ears) will be found at each end of the suture line. These should never be removed since they supply a large share of the blood

supply to the heel flap and disappear later under bandaging A drain is placed in the angle of the wound to be left for forty-eight hours. The heel flap is now fixed with adhesive tape strips to prevent its drifting toward the posterior medial aspect of the stump The sutures are removed at the end of fourteen days. Ace bandaging is continued for three to four weeks thereafter a walking cast is applied and maintained until shrinkage is complete

BOYD AMPUTATION

A long plantar and short, dorsal flap are utilized The incision is begun at the tip of the internal malleolus, passed over the dorsum of the foot at the level of the talonavicular joint and ended one fingerbreadth below the medial malleolus. From this point, the plantar incision is curved downward to cross

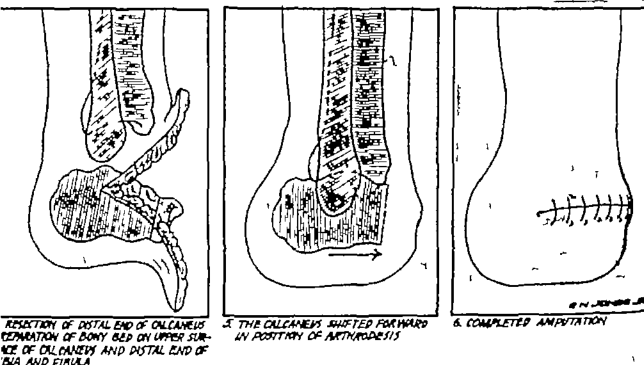


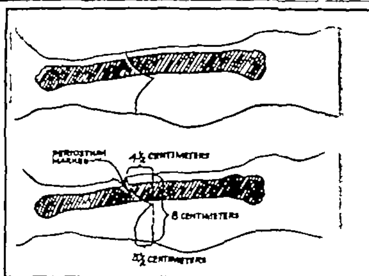
Fig. 563.—Boyd amputation with calcaneotibial fusion.

the sole of the foot at the level of the metatarsal bases, thence upward to the tip of the lateral malleolus. The ligamentous attachments of the calcaneus and tibia are divided by sharp dissection close to bone. The talus is then removed according to the Whitman technic. The anterior portion of the calcaneus is divided in the anteroposterior plane just *distal to the peroneal tubercle*, and the superior tibial and fibular articular surfaces of this bone are denuded of cartilage. These are then adapted for arthrodesis. Any tendons which present themselves in the wound are drawn down and sectioned. The medial and lateral plantar nerves are sectioned to prevent their being subject to pressure. The calcaneus is then shifted forward in its relationship with the ankle joint and mortised into position for arthrodesis, its undersurface being parallel with the ground. A Steinman pin may be passed upward through the heel to transfix the calcaneus to the tibia in this position. The skin flaps are approximated with

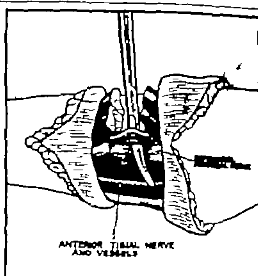
interrupted sutures. A drain is inserted, to be removed in forty-eight to seventy two hours The stitches are removed on the fourteenth day The internal fixation may be removed at the end of four weeks. The patient should not be allowed to bear weight upon the stump until the eighth week. A walking cast is then applied and maintained until arthrodesis is complete

AMPUTATION THROUGH THE MIDDLE THIRD OF THE LEG

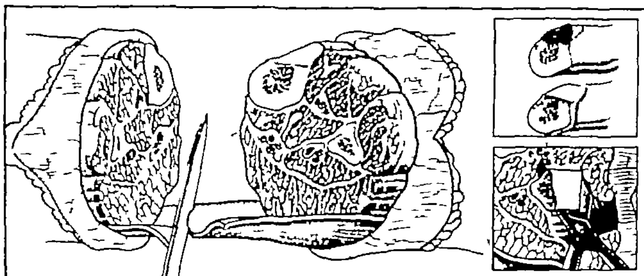
Technic (Carnes) —This amputation is performed with the patient in the supine position. An anterior skin flap slightly longer than the posterior is used The principal feature of this amputation is that it can be carried out step by step with full vision from above The desired bone length is measured from the anteromedial aspect of the tibial plateau adjacent to the patellar tendon The length of the skin flap is determined by taking one-half of the anteroposterior diameter of the leg at this point, adding one-half centimeter to the anterior flap, and subtracting one-half centimeter from the posterior flap This additional length for the anterior flap allows the scar line to fall transversely behind the posterior aspect of the tibia at the desired level The skin incision begins at the intended level of the bone section, swings convexly downward, to end at a similar point on the opposite side of the leg In crossing the tibial crest the incision is carried deeply marking the periosteum in order to establish a point for future measurement. The posterior flap incision is also convexed downward to the point previously measured The incisions are carried to muscle fascia, then reflected upward to the level of bone division by sharp dissection. Because of its retraction, the skin flap cannot be used as a satisfactory measuring stick to determine the saw level The original length of the flap is measured on the bone from the niche made in the anterior surface of the tibial periosteum at the time of the original incision and the bone level is thus re-established. The periosteum and the fascia over the anterior aspect of the leg are incised at this level. A curved hemostat is slipped in the natural cleavage plane at the lateral aspect of the tibia, and allowed to follow along the interosseous membrane, passing over the anterior aspect of the fibula to emerge just anterior to the peroneus brevis muscle The superficial peroneal nerve is identified in the interval between the extensor digitorum longus and peroneus brevis, drawn down gently sectioned, and allowed to retract. The muscles in the anterior compartment are then divided at a point one-fourth inch distal to the saw level, to lie flush with the end of the sectioned bone after retraction. As the muscle section nears completion special care is taken that the anterior tibial vessels and nerves are identified These structures are isolated, sectioned and doubly ligated before they have an opportunity to retract upward within the muscle substance Before the transverse section of the bone, the crest of the tibia is beveled by placing the saw three-fourths inch above the bone level, and carrying it obliquely distalward to cross the bone level $\frac{3}{16}$ inch anterior to the marrow cavity The tibia and fibula are divided transversely at the same level, grasped by bone-holding forceps just below the saw line, and pulled anteriorly and distally to expose the posterior muscles of the calf from above. The posterior muscles are sectioned with a large amputation knife, beginning at a point one-fourth inch below the cut section of the bone, and passing posteriorly and slightly upward until the gastrocnemius aponeurosis is reached. The knife is then



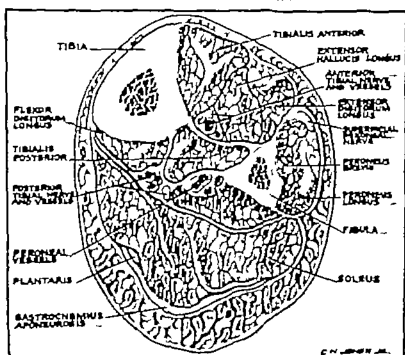
1 INCISION {INCISION STARTS AT MID-DIAMETER
{ANTERIOR FLAP IS 1 CM LONGER THAN POSTERIOR
MEASUREMENT {ANTERIOR FLAP = ½ DIAMETER + ½ CM
{POSTERIOR FLAP ½ DIAMETER ½ CM



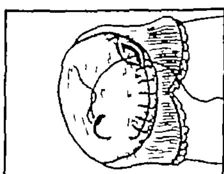
2 SECTION OF ANTERIOR TIBIAL GROUP OF MUSCLES VESSELS AND NERVES



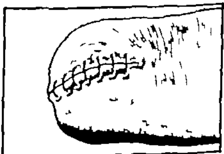
3 COMPLETED SECTION OF THE LEG SHOWING FASCIAL FLAP FROM GASTROCNEMIUS APONEUROSIS
(A) BEVELING OF TIBIAL CREST ¾ FROM SAW LINE ¾ PERIOSTEAL CUFF REMOVED
(B) SECTION OF FIBULA 1¼ ABOVE TIBIAL SAW LINE



4 CROSS SECTION



5 SUTURE OF FACIAL FLAP



6 COMPLETED AMPUTATION

Fig [illegible].—Amputation through middle third of leg.

turned and drawn downward parallel to the fibers of this structure until fascia of sufficient length is obtained to cover the end of the stump The gastrocnemius aponeurosis is next divided transversely at that point During the process of muscle section dissection should be carried out slowly, that the tibial nerve may be identified and sectioned. The posterior tibial vessels and nerves are similarly identified and doubly ligated as they are encountered. Severance of the distal portion of the limb is now complete. The cut end of the fibula is identified, and this bone is exposed subperiosteally from below to a point one and one fourth inches above the end of the tibia here, it is divided by a Gigli saw or bone-biting forceps. The distal end of the fibula is removed to give wide exposure of its investing periosteum, the latter is dissected free under vision, that the troublesome bleeding which is usually encountered at this point may be controlled more readily The flap of gastrocnemius fascia is brought forward over the end of the stump and fixed to the anterior muscle fascia and periosteum with plain catgut sutures If the muscle is bulky at the sides of the stump, a wedge of muscle is removed at the desired point. The skin flaps are approximated and fixed with interrupted sutures.

If one does not wish to cover the end of the bone with a fascial flap the step involving the preparation of the gastrocnemius aponeurosis for this purpose is omitted.

Tendoplastic Method (Kirk)—In this amputation a long anterior and short, posterior flap in the ratio of 3 2 is utilized. Kirk points out that the stump should be measured from the insertion of the internal hamstrings, since only the portion distal thereto can be contained within the socket of the prosthesis. The anterior incision begins halfway between the anterior and posterior aspects of the leg on the medial side just above the intended saw line, passes distally and laterally thence proximally to end at the mid portion of the lateral aspect of the leg opposite the point of origin. The posterior flap is cut in a similar manner The anterior flap is now dissected to a point just above the saw line, while the posterior flap is dissected upward about one-half inch. The posterior skin distal to the incision is stripped downward for a distance of two to three inches in preparation for the creation of a partial flap of gastrocnemius aponeurosis at a later point in the operation. The anterior tibial muscle group with its covering fascia, is cut transversely about one-half inch below the intended saw level, to permit its retraction upward to the saw line after section A long bladed amputation knife is inserted through the posterior muscles just behind the fibula and tibia at the saw level The knife is then drawn posteriorly and distally through the calf muscles to form a triangular flap of muscle, tendon, and fascia, of sufficient length to cover the end of the stump The periosteum is now cut circumferentially at a point one-fourth inch above the intended saw line over the tibial crest, however the knife is carried upward for an additional one-half to three-fourths inch, to allow for *beveling* The periosteum is then stripped downward. The soft tissues about the fibula are next dissected free for a distance of one inch. The tibial crest is now beveled, starting one-half inch above its intended line of section and the tibia is *sectioned* at a right angle to the long axis of the leg The fibula is now divided by a Gigli saw at a level one inch above the cut surface of the tibia The periosteal fringes are removed and the bone dust is washed away with normal saline solution The

posterior flap of muscle, previously formed is now thinned by excision of the muscle substance until it is not more than one-half inch thick in its base, and one-eighth inch thick at its apex A test fit is made by approximation of this flap to the anterior muscle fascia and the periosteum on the medial aspect of the tibia. Any excess tissue is trimmed away Following section of the nerves above the level of the bone end and complete hemostasis, the flap is sutured to the anterior periosteum and muscle fascia by interrupted catgut sutures. The skin is approximated by interrupted sutures, and a drain inserted.

AMPUTATION THROUGH THE UPPER ONE-THIRD OF THE LEG

Amputation through the upper one-third of the leg is carried out upon the same principles as the below knee amputation of normal length. Certain variations in technic are necessary however, because of the need to conserve all tissues to provide as much length as possible, and to shape the stump so that it will have no redundancy Since each case presents an individual problem, no definite technic can be followed. The surgeon should, however be guided by the following general principles the skin flaps may be fashioned from any available skin, allowing the suture line to fall where it may preferably avoiding the anterior aspect of the tibia and the area around the metaphyseal flare. If a sufficient amount of gastrocnemius fascia is not available, the fascial flap covering of the end of the stump may be provided from the anterior or lateral aspects of the leg The periosteum and bone are treated in the usual manner though the fibula is *always* excised to give a more conical shape to the stump and to afford better fitting of the prosthesis.

Section of the hamstring tendons allows the stump to fit down farther within the limb and thus affords greater functional length. To accomplish this, the hamstrings are sectioned through the open wound at the time of plastic repair *The biceps femoris, semimembranosus, and gracilis tendons are severed at their* insertions and allowed to retract (Blair and Morris)

DISARTICULATION OF THE KNEE (ROGERS)

The surgeon stands on the opposite side of the table from the extremity to be removed. No tourniquet is used. A long anterior flap extending one inch below the tibial tubercle, and a broad, posterior flap extending one inch below the flexor crease of the knee are employed. The deep dissection begins with the section of the four inner hamstrings at their tendinous insertions, exposing the popliteal space The popliteal artery is severed and ligated just below its superior geniculate branches, and the tibial and common peroneal nerves are sectioned. The dissection then proceeds across the anterior aspect, through the soft tissues. These are reflected en masse and the patellar tendon is freed as close to the tibial tubercle as possible. The anterior flap now consists of skin, fascia, patellar tendon, and synovial membrane. The tendon of the biceps femoris and the iliotibial band are next identified and divided near the tibia. The posterior flap is reflected upward, and the deep dissection is completed by cutting the collateral and cruciate ligaments close to their femoral attachments. The muscles of the thigh are attached to the end of the stump under normal tension. The patella is either mortised into a groove on the anterior aspects

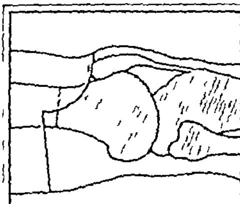
of the femur, or its opposing cartilaginous surfaces are denuded and the bone is fixed to the femur with a nail The patellar tendon is now drawn posteriorly within the intercondylar groove and fixed to the ends of the hamstring tendons The sartorius muscle and the iliotibial band are sutured to the fascial portion of the extensor mechanism The skin flaps are then approximated with interrupted skin sutures

END BEARING AMPUTATIONS THROUGH THE THIGH

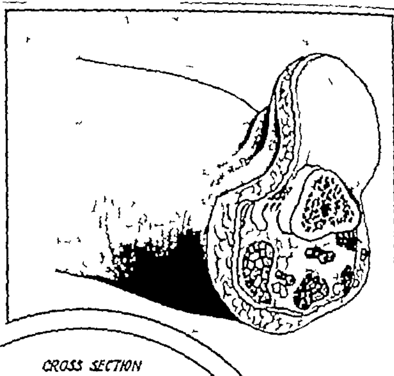
Aperiosteal Supracondylar Tendoplastic Amputation (Kirk)—In this amputation, the osteotomy site is one and one-fourth inches above the articular surface of the anterior aspect of the femur A long anterior and short, posterior flap are necessary Dissection of the anterior flap is begun just above the osteotomy site in the mid portion of the medial aspect of the leg passed downward just below the upper margin of the patella, and thence continued upward to the mid lateral aspect of the thigh The posterior flap has a slight downward convexity, and is only one-fourth the length of the anterior flap The anterior incision is deepened to the bone at the level of the retracted skin. The quadriceps tendon is next severed at its patellar insertion The entire flap consisting of skin and musculotendinous tissue, is reflected upward, and the underlying synovium is resected The posterior fascia is cut at a point one-fourth inch distal to the skin incision and the soft tissues are sectioned to bone A circular incision is made through the periosteum the bone sectioned, and a one-fourth inch periosteal cuff removed. Major vessels are isolated and doubly ligated with catgut. The sciatic nerve is isolated gently drawn down, sectioned, and ligated with a single strand of fine catgut. Other nerves are divided and allowed to retract. The tourniquet is removed, and bleeding controlled The flaps are now approximated the fascia of the anterior flap first being sutured to that of the posterior flap and the skin then approximated with interrupted sutures A drain is inserted in the wound (Fig 565)

The Rounded Epicondylar Tendoplastic Amputation (Slocum)—Using a long anterior and a short, posterior flap, the bone is divided at the level of the epicondyles, shaping and rounding the end of the bone (Fig 566)

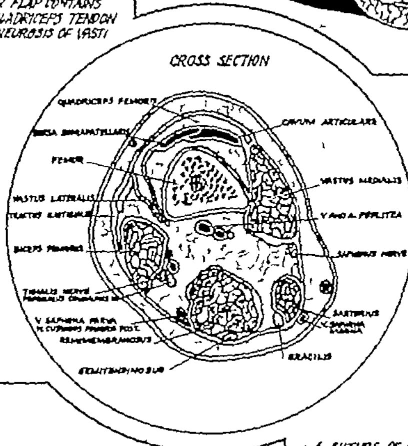
The skin incision is begun at the adductor tubercle of the medial epicondyle passed distally and laterally to cross in front of the knee at the level of the insertion of the patellar tendon to the tibial tubercle, and thence carried proximally along the lateral border of the knee to end at the upper border of the lateral epicondyle of the femur The posterior incision which is approximately three-fourths inch in length, forms a gentle arc between the two ends of the incision The anterior incision is now deepened through the tendon and fascia, exposing the anterior aspect of the knee joint. The flap is reflected upward, and separated from the patella by sharp dissection Any excessive fat is trimmed away The synovium is removed the periosteum is incised and the bone sectioned so the cut surface will be parallel to the ground when the patient is standing The entire end of the bone is then beveled and smoothed, beginning one-half inch from the periphery and beveling its entire circumference at a 45-degree angle The shape of the head should be roughly hemispherical except for the broad, flattened end. The severed femoral condyles are now drawn downward to expose the posterior soft tissues, and the latter are sectioned in an

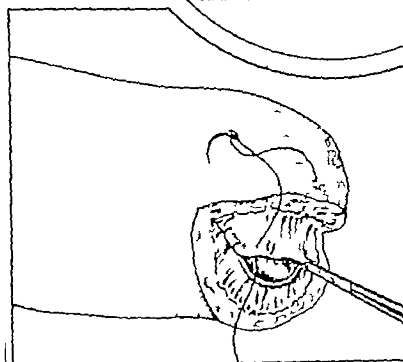


1. SKIN INCISION AND BONE LEVEL



2. COMPLETED FLAPS
(A) 1/4 PERIOSTEAL CUFF
(B) FASCIA 1/4 LONGER THAN SKIN
(C) THE ANTERIOR FLAP CONTAINS SKIN, FASCIA QUADRICEPS TENDON AND THE APONEUROSIS OF VASTI





4. SUTURE OF QUADRICEPS TENDON TO THE POSTERIOR FASCIA

5. COMPLETED AMPUTATION

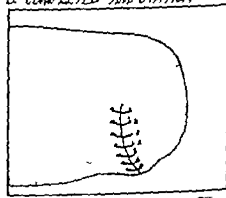


Fig. [illegible].—End-bearing amputation through thigh by aperiosteal supracondylar tendoplastic technic (Kirk)

anteroposterior direction. The major vessels are isolated clamped and sectioned. The nerves are sectioned cleanly and tied with a single strand of catgut. The amputation having been completed, the major vessels are then ligated and the clamps are released. The tourniquet is freed and bleeding controlled. The anterior flap of tendon fascia and skin is approximated to the posterior flap and the fascia of the two flaps fixed with plain catgut The skin is closed with interrupted silk sutures. A drain is inserted and dry dressings and elastic bandage compression over sheet wadding are applied.

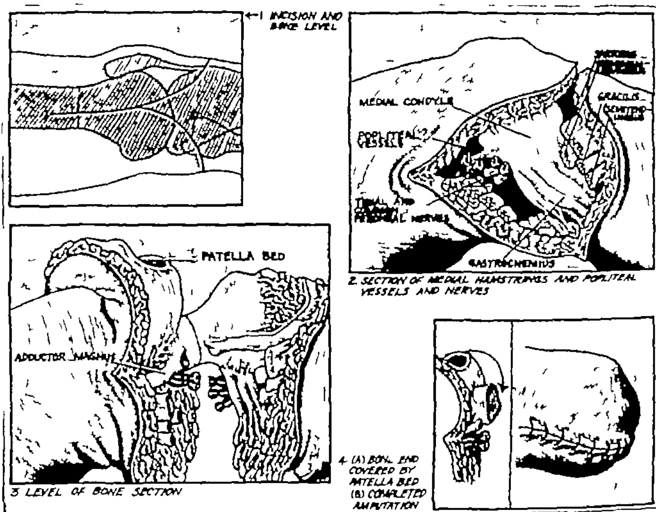


Fig 567 —Callander end-bearing amputation.

Technic (Callander) —In amputation above the level of the foot for peripheral vascular disease the Callander procedure is preferable The bone is divided at the supracondylar level. Exceptionally long anterior and posterior skin flaps are employed to facilitate free drainage, and all muscles are sectioned through their tendinous insertions. Deep sutures are unnecessary

The patient is placed on his back on the operating table with the knee flexed to 150 degrees by means of a sandbag beneath the popliteal space. The surgeon stands on the opposite side of the operating table from the leg to be amputated. Beginning on the inside of the thigh at a point three fingerbreadths above the femoral condyle the incision is carried distally in the groove between the vastus

medialis and sartorius muscles to the level of the insertion of the patellar tendon at the tibial tuberosity. The thigh is internally rotated, and a second incision is made, beginning three fingerbreadths above the lateral femoral condyle and following the groove between the fascia lata and biceps femoris tendon to the tibial tuberosity where it joins the first incision. The posterior incisions start from the original incisions at the level of the femoral epicondyles and swing downward to meet at a mid point on the posterior aspect, forming a flap equal in length to that on the anterior aspect. The thigh is now externally rotated

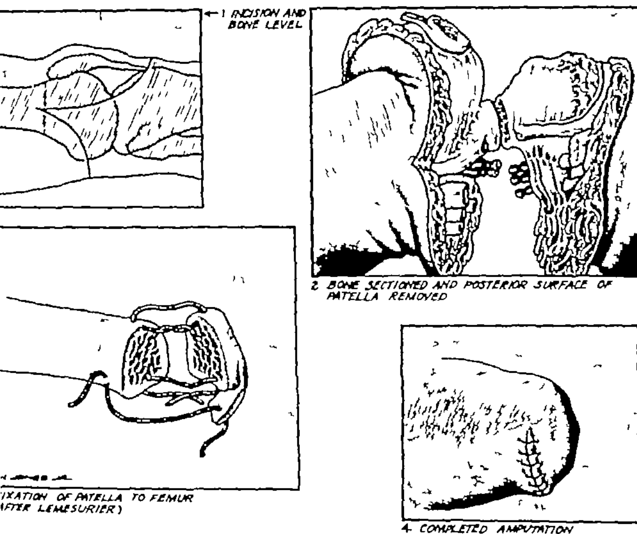


Fig. 448.—Stokes-Gritti end bearing amputation (LeMesurier)

and the medial fascia sectioned. The internal hamstring tendons are sectioned at their tibial insertions and allowed to retract. The insertion of the adductor magnus is identified and divided at the adductor tubercle. The popliteal artery and vein are identified, clamped, and doubly ligated at the most distal point possible in the popliteal space. The sciatic nerve or its branches are then cleanly sectioned. The knee is now rotated internally; the lateral deep fascia is divided, and the biceps tendon and fascia lata are sectioned near their tibial attachments. The knee is next placed in extension, the anterior flap is deepened into the knee joint and reflected upward, and the patella is removed from its

bed by sharp dissection No attempt is made to excise the synovial membrane. The femur is divided transversely at the level of the adductor tubercle, and the bone smoothed The anterior and posterior flaps are then allowed to fall together loosely and are approximated by four to six interrupted sutures The flaps are quite loose and may often extend an inch or more beyond the end of the bone Retraction takes place rapidly by the end of a week or so there is no excess skin length and the suture line has been drawn upward on the posterior aspect.

Stokes-Gritti Amputation (LeMesurier) —This procedure embodies the use of a short posterior and a long anterior flap which contains the patella. The latter is rotated upward 90 degrees, and then arthrodesed to the femur in the supracondylar region (Fig 568)

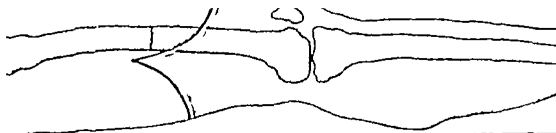
The anterior flap is formed by an incision which starts in the midlateral aspect of the thigh one inch above the upper border of the patella and swings downward to a point one-half inch below the lower pole of the patella, thence upward to a point one inch above the patella on the mid point of the medial side. The posterior incision connects the two ends of the first incision and forms a flap approximately one half inch in length The anterior flap is deepened into the joint by section of the capsule and patellar tendon, the flap is reflected upward, *the suprapatellar bursa resected* and *the posterior one half of the patella*, including the articular cartilage, is removed. The posterior flap is retracted upward, and the muscles divided by a slightly oblique section which reaches the femur just above the condyle. The vessels are isolated and ligated, and the nerves sectioned and allowed to retract above the bone level The femur is severed parallel to the ground, assuming the patient to be in the standing position The cut surface of the patella is rotated 90 degrees, and approximated to the cut surface of the femur the patella is maintained in this position by two stout catgut sutures passed through holes drilled in both bones, one anteriorly and one posteriorly The patellar tendon is sutured to the periosteum on the posterior aspect of the femur The skin is closed with interrupted sutures, and a drain inserted into the wound.

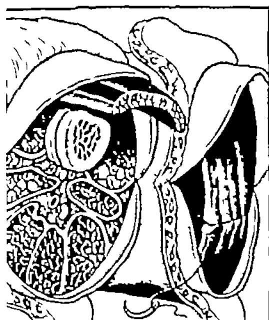
ISCHIAL-BEARING AMPUTATIONS

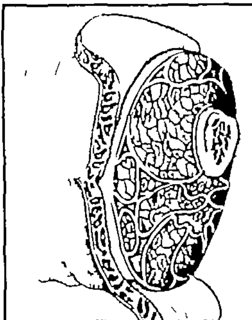
A long anterior and short, posterior flap are used The fascia overlying the quadriceps muscle is divided in a line with the anterior incision and the underlying muscle is beveled proximally to the osteotomy site. The muscles should not exceed one-half inch in thickness. The posterior fascia is divided at the incision line and reflected upward The posterior thigh muscles are sectioned transversely to retract to the saw line. The periosteum is incised circumferentially and the bone divided The femoral and deep femoral artery and veins are isolated and doubly ligated. The sciatic nerve is identified, injected with Novocain and ligated. The tourniquet is removed and hemostasis completed. The anterior myofascial flap is now fixed to the posterior fascia and the skin closed with interrupted sutures.

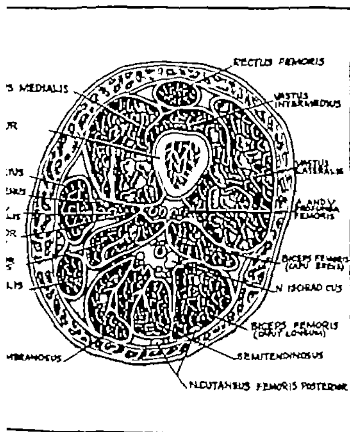
DISARTICULATION OF THE HIP

Technic (Boyd) —An anterior racquet type of incision is begun at the anterior-superior spine and curved downward and medially almost parallel with Poupart's ligament, to a point on the inner aspect of the thigh five centimeters









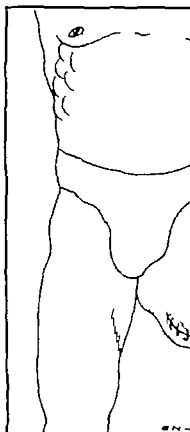


Fig. [illegible] —Ischial bearing amputation through middle third of thigh.

below the origin of the adductor muscles. The femoral artery and vein are isolated and ligated and the femoral nerve is injected with Novocain and divided. The incision is then continued around the posterior aspect of the thigh approximately 5 cm. distal to the ischial tuberosity, thence along the lateral aspect of the thigh about 8 cm distal to the base of the greater trochanter. From this point, it curves upward, joining the original incision below the anterior-superior iliac spine. The sartorius muscle is detached from the anterior-superior iliac spine and reflected distally, the rectus femoris is detached from the anterior inferior iliac spine and also reflected distally, and the pectineus is divided approximately

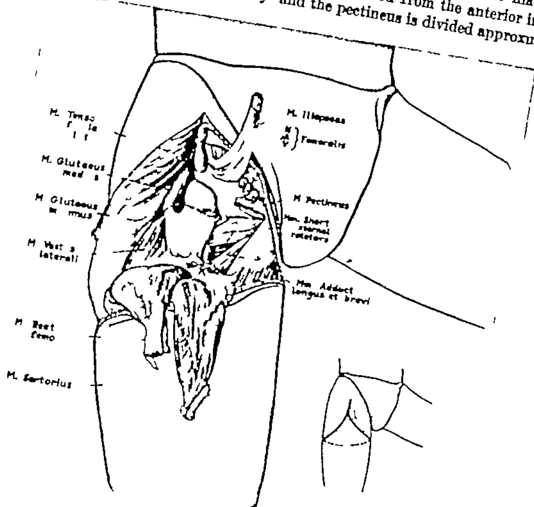


Fig. 570.—Boyd anatomic disarticulation of hip. At this stage, femoral vessels and nerves have been ligated, and sartorius, rectus femoris, pectineus, and iliopsoas muscles have been detached. Insert shows line of skin incision. (From Boyd, H. B. Surg., Gynec. & Obst. 84: 346 1947.)

one-fourth inch from the pubis. The thigh is rotated externally to bring into view the lesser trochanter and iliopsoas tendon. The latter is severed at its insertion and reflected upward. The adductor and gracilis muscles are next detached from the pubis and that portion of the adductor magnus which arises from the ischium is severed at its origin. The plane between the pectineus and the obturator externus and short rotators is delineated and the branches of the obturator artery are ligated. The obturator externus muscle is later detached from its insertion into the femur. If the muscle is divided at its origin, the

obturator artery may be severed and may retract into the pelvis, leading to hemorrhage which is difficult to control

The thigh is rotated internally and the gluteus medius and minimus muscles are detached from their insertions into the greater trochanter, and retracted upward. The fascia lata is divided below the insertion of the tensor fasciae latae muscle in the line of the skin incision, together with the lowermost fibers of the gluteus maximus muscle and the tendon of the gluteus maximus is separated from its insertion into the linea aspera and retracted upward. The sciatic nerve is injected with Novocain and divided The short rotators of the hip, i.e., the pyriformis, gemelli, obturator internus, obturator externus and quadratus

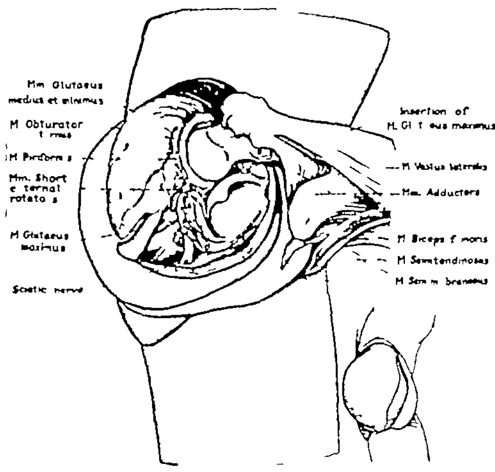


Fig. 571.—Same as Fig 570—Glutei separated from insertions, sciatic nerve divided, short rotators severed, and hamstring muscles detached from ischial tuberosity Insert shows final closure of stump. (From Boyd H. B. Surg., Gynec. & Obst. 84: 346, 1947)

femoris, are divided at their insertions into the femur and the hamstring muscles are then severed from the ischial tuberosity The disarticulation is now complete except for incision of the capsule of the hip joint near the acetabulum and division of the ligamentum teres.

The disarticulation having been completed the gluteal flap is brought forward, and the distal portion of the gluteal muscles is sutured to the origin of the pectineus and adductor muscles. The skin is closed in the routine manner The gluteal flap is sufficiently large to permit closure without tension. A drain is placed in the inferior portion of the incision to be removed twenty four to thirty-six hours later

Posterior Flap Technic.—Beginning at the level of the inguinal ligament, the incision is carried distally over the femoral artery a distance of four inches, thence to the inside of the thigh to form a long posterior internal flap of sufficient length to cover the end of the stump It is continued laterally and proximally over the greater trochanter, and finally anteriorly to the starting point of the racquet incision. The femoral vessels are isolated and ligated. In making the queue of the incision, the femoral nerve is sectioned to fall above the inguinal ligament. The thigh is placed in wide abduction and the adductor muscles are divided at their pubic insertions. The two branches of the obturator nerve are sectioned to fall away from pressure areas. The sartorius and rectus femoris are severed at their insertions to the anterior superior spine The thigh is now placed in moderate adduction and internal rotation, and the tensor fascia lata and muscles attached to the upper end of the greater trochanter are divided close to the bone at that level. The thigh is next placed in extreme abduction, and the gluteus maximus is divided at the distal end of the posterior skin flap *The sciatic nerve is injected with Novocain and sectioned.* The joint capsule is then divided completing the disarticulation. Finally the long posterior flap containing gluteus maximus and skin is swung forward and sutured to the anterior margin of the incision.

HINDQUARTER AMPUTATION

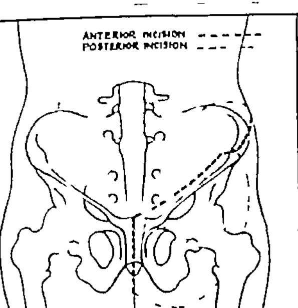
Before the operation is undertaken the surgeon should assure himself that the lower bowel has been thoroughly cleansed on the morning of surgery and that the bladder has been emptied by catheterization in the operating room. Ample quantities of blood and plasma should be available. The patient is then placed in the full lateral position and the blood expressed from the leg by elevation and the application of a tight compression bandage

The operation, according to the technic of King and Steelquist, falls naturally into three parts anterior perineal, and posterior

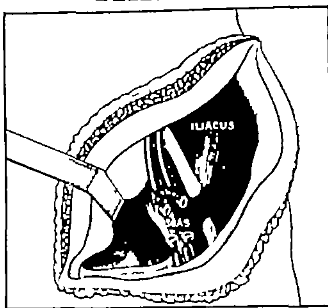
The Anterior Portion—The incision begins at the pubic tubercle, extends upward and outward along the inguinal ligament to the anterior-superior iliac spine, and posteriorly along the iliac crest. The abdominal muscles and inguinal ligament are detached from the iliac crest, and the iliac fossa is opened between the peritoneum and iliacus. At the pubis the inguinal ligament and the rectus abdominis tendon are severed the cord is retracted medially the space of Retzius is opened and the bladder is retracted into the pelvis. The external iliac artery vein, and femoral nerves are now located, tied, and cut. This anterior wound is now tightly packed with dry gauze.

The Perineal Portion.—The extremity is widely abducted and the incision carried downward and outward from the pubic tubercle, along the pubic and ischial rami to the ischial tuberosity The subcutaneous rami are exposed and the ischio-cavernosus and transversus perinei are elevated subperiosteally from their inferior surfaces. An osteotome is used to divide the ligaments and fibrocartilage of the symphysial synchondrosis.

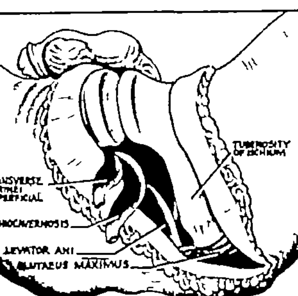
Posterior Portion.—The incision over the iliac crest is carried posteriorly to the posterior-superior iliac spine at this point, it is turned abruptly outward to the greater trochanter then continued posteriorly and distally following the gluteal crease into the perineum to join the perineal portion of the incision.



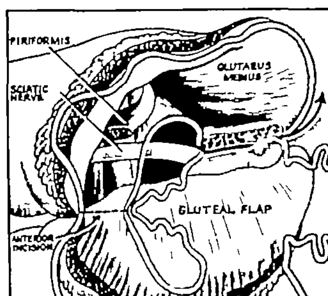
NCISION



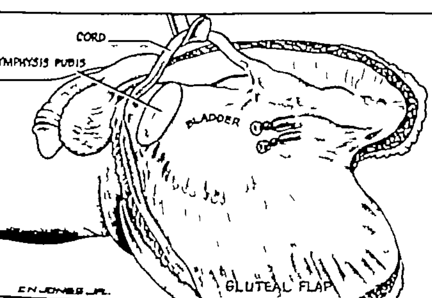
2 ANTERIOR INCISION (BLADDER RETRACTED) SECTION OF FEMORAL VESSELS AND NERVES



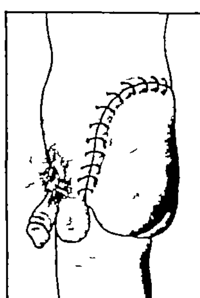
PERINEAL VIEW DIVISION OF SYMPHYSIS PUBIS AND SECTION OF PERINEAL MUSCLES



4 POSTERIOR VIEW SHOWING SECTION OF ILIUM (WHITE LINE INDICATES PELVIS)



LATERAL VIEW AFTER REMOVAL OF EXTREMITY



6 COMPLETED AMPUTATION

Fig. 572.—Hindquarter amputation.

The posterior and inferior edges of the gluteus maximus are exposed and its aponeurosis is divided in line with the skin incision, the muscle is then elevated, forming a large flap of skin, fat and gluteus maximus muscle. On retracting this flap the gluteus medius and rotator muscles of the hip, and the sciatic nerve are brought into full view The pyriformis is severed, and the sciatic nerve is ligated and divided. A wire saw is now passed into the pelvis through the greater sciatic notch and is brought out over the iliac crest just in front of the sacroiliac joint The saw is carried down through the ilium, and finally the sacrotuberous and sacrospinous ligaments are severed. The innominate bone is now quite movable, it is rotated externally with the extremity to give a wide intrapelvic exposure. After ligation and division of the obturator vessels and nerve the psoas muscle is cut at the level of the sacroiliac joint. The elevator ani is then severed close to its origin on the pelvic surface of the pubic bone, thus completely freeing the innominate bone and the entire lower extremity To effect closure, the gluteus maximus flap is drawn forward and sutured to the rectus abdominis, the lateral abdominal, the quadratus lumborum, and the psoas muscles. The skin sutures are loosely placed over three or four soft rubber drains, the latter to remain in situ for forty-eight to seventy two hours

After Treatment.—Early movement and turning in bed is encouraged following operation Catheterization is usually necessary for two or three days. Morphine sulphate is given in sufficient quantities to relieve pain and allay the patient's marked apprehension To obviate the necessity for bowel movement the patient is allowed only a liquid diet for one week

OPEN AMPUTATION

Open amputation as the name implies, is one wherein the skin is not sutured over the end of the wound. The operation is a temporary one and must always be followed by a second amputation to effect final repair of the stump Its purpose is the control and elimination of infection, that final amputation may be carried out without danger of breakdown of the wound. The open type should be employed in the presence of a traumatic wound with extensive tissue destruction (1) if unavoidable delay has made infection probable (2) if actual sepsis, controlled or uncontrolled, is present and (3) in traumatic amputations near the site of election, wherein every inch of stump length must be conserved In this last type of case, the use of open amputation is a precautionary measure *if sepsis should develop important length would probably be lost.*

Principles of Open Amputation

Open amputation should be carried out at the lowest possible level consistent with the control *of infection even though this should fall well* below the site of election. Thus, the maximum amount of tissue will be available for the final repair

There are two general types of open amputation (1) the circular open amputation and (2) *open amputation with skin flaps.* Except in special cases, the circular open amputation is the method of choice. Technically it meets all the requirements in that it affords wide open drainage, eliminates dead space, removes necrotic tissue, precludes osteomyelitis and soft tissue infection, and

preserves valuable bone length Further, the operation is rapidly and easily executed, and does not require extensive technical knowledge

In performing an open amputation with flaps, the skin is cut in the pattern of the formal flap of the ideal amputation at that level, although somewhat longer This type of skin treatment is employed on the premise that secondary closure will be carried out early to avoid an open granulating wound and minimize subsequent dressings It affords no better drainage than a circular open amputation and often sacrifices valuable skin which may be used at future repair

Regardless of the method used, any viable skin which extends to the end of the bone or slightly beyond should be preserved

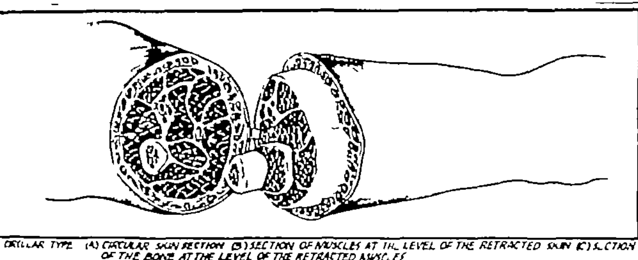


Fig 572.—Open amputation.

CIRCULAR OPEN AMPUTATION

A tourniquet should always be used if possible The bone should be severed at the most distal site which will eliminate the danger of actual or potential sepsis.

Technic.—The skin is incised in a circular manner to the level of the deep fascia, and allowed to retract The muscles are then divided at the level of the retracted skin this should be done slowly that unequal retraction in different muscle groups will not result in an uneven wound surface The bone is then sectioned at the level of the retracted muscle. No attempt is made to form a periosteal cuff otherwise, necrosis of the bone end may follow All vessels which can be identified are ligated the major vessels require double ligature The nerves are identified and sectioned to fall just above the open surface of the wound if divided at a higher level the nerves will be difficult to find at the final operation. Tendons are sectioned so as not to fall above the wound level Occasionally, an infection will extend above the level of amputation, being confined to a single fascial space If the infection is not endangering the life of the patient, the infected areas should be drained through auxiliary longitudinal incisions in preference to reamputation at a higher level. These extra incisions are best placed on the medial or lateral aspect of the stump, since scars in this area are least likely to cause trouble in a prosthesis When the amputation

is completed, the wound is dressed with petrolatum gauze followed by dry gauze dressing skin traction, and elastic bandage compression

After Treatment.—Skin traction should always be applied at the time of operation or as soon afterward as possible. Of the several methods of applying traction, the use of stockinet is by far the most satisfactory The leg is first thoroughly cleansed, then painted with a heavy coating of skin glue sufficient to penetrate the stockinet well. After the glue becomes tacky sterile stockinet of an appropriate size is rolled up over the entire length of the stump about six to eight inches extending beyond the end. The stockinet is split on the medial and lateral sides to the level of the wound and the dressings previously applied are tucked down to fit its inner contours. The free end of the stockinet, which is now in two pieces, is drawn down with moderate tension and tied firmly over the wound in a single, simple knot, holding the dressings snugly An elastic bandage is then molded well about the end of the stump This not only molds the terminal portion of the stump but also ensures fixation of the stockinet and minimizes edema. A traction rope is next fastened about the knot in the stockinet, and three to five pounds of traction is applied. This amount may be increased later to between five and ten pounds, depending upon the tolerance of the patient.

After several weeks, the granulations will become firm and a dry dressing alone may be used. The original dressing should not be changed during the first week unless drainage is excessive or infection is present. When the dressings are changed the traction is removed and the stockinet folded back to the level of the wound. The skin is cleansed about the granulating area, and new dressings are applied. Local chemotherapy has no particular effect on the healing of the wound and is not necessary Traction is continued until the granulating area is fixed by cicatrix or healed by scar

Open Amputation With Skin Flaps

This technic is essentially the same as that used in the circular type of amputation, with the exception of the treatment of the skin. The incision is begun at the bone level, and the flaps, preferably posterior and anterior are cut long Traction is somewhat more difficult to apply but is not less important than in the circular type

SPECIAL CONSIDERATIONS IN OPEN AMPUTATION OF THE FOREFOOT IN THE PRESENCE OF VASCULAR DISEASE

The minor amputations of the foot for peripheral vascular disease differ from open amputations in other regions. Here, minor trauma or minimal infection may be followed by such disastrous results that the foot and, indeed, the life of the patient may be seriously jeopardized. If sepsis becomes established within the forefoot amputation above the knee is usually imperative. If infection or gangrene is restricted to the toes, open amputation is the procedure of choice, provided certain requirements are observed the skin temperature, color and pulse must be normal the general nutrition of the foot must be good and there must be no ischemic pain If these conditions are satisfied, open amputation may be carried out according to the following general principles

portion of the sides of the femoral condyle are removed so the flare of the femoral metaphysis will not be a barrier to skin traction. The tourniquet is removed, hemostasis completed and traction applied.

OPEN DISARTICULATION AT THE HIP JOINT

This procedure is carried out through an anterior racquet incision made in the following manner The femoral artery is palpated beneath Poupart s ligament, and the queue of the racquet is begun at this point and carried longi tudinally downward a distance of three and one-half inches. The wound is deepened to expose the femoral artery and vein and these are isolated, doubly ligated and sectioned and allowed to fall within their bed. The incision is now carried across the medial aspect of the leg at a point three inches below the in ferior ramus of the pubis, crossed over the back of the thigh and passed over the inferior portion of the greater trochanter then continued upward around the leg to join the longitudinal limb of the incision. The leg is placed in adduction and the muscles attached to the greater trochanter are sectioned at their ten dinous insertions The anterior thigh muscles are sectioned at the level of the skin as far as Poupart s ligament. The leg is now placed in marked abduction and the adductor muscles are divided near the bone. The capsule of the hip *joint is next exposed and divided circumferentially* and the *head of the femur* is dislocated from the acetabulum by abduction external rotation and extension. The ligamentum teres is divided A large amputation knife is then placed be- tween the femur and gluteus maximus, drawn downward and outward to the end of the skin flap and carried posteriorly to section the posterior thigh muscles transversely The extremity is removed and any necrotic tissue or excess muscle bulk trimmed away The wound is dressed with petrolatum jelly gauze followed by a dry dressing and an elastic bandage hip spica applied

SKIN GRAFTS

In the foot and hand, and in those areas alone, the open amputation may be closed temporarily In any other part of the extremities, such a procedure would make ineffective the skin traction which is so important in achieving length. Un less more than the usual skin length is available beyond the level of the wound, closure is accomplished by means of a free skin graft. Early closure is per formed in order to avoid a deep cicatrix, to maintain the cleanliness of the wound, and to obviate a painful dressing The graft may be applied as soon as is compatible with a take. Occasionally such a graft may be allowed to re- main if further reconstruction is not necessary and if not situated in an area which is subject to pressure.

Preparation of the Open Amputation Stump for Final Closure.—The final repair of the open amputation wound is an elective procedure. It should be performed in a clean field, the general condition of the patient being at its best in order to insure the maximal resistance to infection. As soon as traction is removed, steps should be taken to prepare the stump itself for final closure, since the stump must meet certain specifications before this final procedure is under- taken. It must be completely free from edema, for the reason that edema is an indication of circulatory deficiency in the presence of infection. The most ef fective measures for the elimination of edema are bed rest, and elevation of the

extremity, accompanied by bandaging and physical therapy The skin must be normal in character and free from all crusts, desquamation, fat, and dermatitis. The terminal granulating area must be relatively free from infection and must present firm, cherry red granulations This is best accomplished by thorough debridement, dakinization, saline packs, whirlpool baths, and physical therapy All deep infection must be destroyed by deep incision and drainage. If skin grafts have been erroneously applied, they must be excised and traction instituted In addition during this period, muscle training should be instituted and great care taken to prevent contractures It should be emphasized at this point that skin grafts for other areas should never be removed from the amputation stump since such defective areas may cause trouble when the artificial member is worn.

Final Repair of the Open Amputation Stump—The final repair of an open amputation stump is carried out in order to provide a well healed, well-shaped stump which is capable of bearing weight within the prosthesis and withstanding subsequent pressure and strain Either of three types of procedure may be employed (1) reamputation and final closure at a higher level (2) plastic repair of the amputation stump (3) revision of the stump Reamputation needs no comment here since the technic is identical to that followed in final definitive amputation elsewhere The technics of plastic repair and revision however, require some elaboration.

Plastic repair includes the remodeling of the soft tissues, and the provision of an adequate covering of skin without disturbing the bone The scar and granulating area are resected from the end of the stump by sharp dissection. The skin incision is made through normal healthy tissue which contains a good layer of subcutaneous fat, and is placed to form flaps, the distal edges of which are as close as possible to the thick heavy scar bounding the terminal granulating wound. The flaps are then undermined in the cleavage plane between the superficial and deep fascia and reflected upward for a distance of one to three inches, depending upon the mobility of the skin to be used to cover the bone end. The dense layer of scar overlying the end of the bone and muscle is excised to a well vascularized tissue Muscle tissue is excised as necessary to eliminate any large, bulky, redundant masses which would inferfere with the proper shaping of the stump Since the muscle is firmly bound to the sides and end of the bone by scar tissue retraction need not be feared, and fascial flaps are unnecessary The bone is left undisturbed or may be rounded slightly and beveled to meet the needs of the local situation. Any major vessels within the field are isolated and ligated this should not be a serious problem, since the larger vessels have usually been thrombosed following the primary amputation. The nerves are isolated, drawn down and sectioned. The tourniquet is removed and hemostasis completed. The skin is drawn down over the end of the stump and trimmed to permit approximation of the edges of the wound under normal tension No general rule governs the position of these flaps covering must be effected in any way possible. It is usually desirable to place the scars as nearly as possible in the position recommended for ideal amputation of the area Following the closure of the wound, a drain is inserted and a dry gauze dressing and elastic bandage are applied. The use of skin traction following final repair of an open amputation is not recommended The skin should never be approximated under sufficient tension to require traction

The term revision applies to removal of the terminal granulating area of scar and a moderate amount of bone, in an effort to create a stump as nearly ideal as possible The surgical technic is essentially the same as that for plastic repair differing only in the fact that bone is removed The terminal granulating area and scar are excised through good skin near the scar tissue border and the soft tissues and stump are remodeled. The bone is next excised so as not to protrude beyond the lateral protective muscle surface it is then beveled and smoothed, and washed with normal saline to remove all bone dust. The blood vessels and nerves are cared for as previously described. After plastic rearrangement of the skin, closure is effected by interrupted skin sutures. Dry dressings and an Ace bandage are applied. Traction is omitted.

References

Alldredge, R H Symposium on Surgical Diagnosis Indications for the Syme Amputation, S. Clin. North America 26 422, 1946.
Alldredge, R H., and Thompson, T C. The Technique of the Syme Amputation, J Bone & Joint Surg 28 415, 1946
Alldredge, R. H.: Major Amputations, Surg., Gynec. & Obst. 84 59 1947
American Medical Association: Handbook on Amputations, Chicago, Amer Med. Assoc., 1942.
Blair Harry C., and Morris, H. D: Conservation of Short Amputation Stumps by Tendon Section J Bone & Joint Surg 28 427 1946
Boyd, H. B: Amputation of the Foot, With Calcaneotibial Arthrodesis, J Bone & Joint Surg 21 997 1939
Boyd, H. B.: Anatomic Disarticulation of the Hip, Surg., Gynec. & Obst. 84 346 1947
Callander, C. L. Tendinoplastic Amputation Through Femur at Knee Further Studies, J A. M. A. 110 113 1938.
Carnes, J: Below Knee Amputation, Personal communications 1947
Ghormley R. K., Henderson, M. S., and Lipscomb P R. Interinnomino-Abdominal Amputation for Chondrosarcoma and Extensive Chondroma; Report of Two Cases, Proc. Staff Meet., Mayo Clin. 19 193 1944
Great Britian Ministry of Pensions Artificial Limbs and their Relation to Amputations, London, H. M. S. O., 1939
Harris, R. L Amputations, J Bone & Joint Surg. 26 626, 1944
Kessler H. H. Cineplastic Amputation, Surg., Gynec. & Obst. 68 554 1939
King D., and Steelquist, J Transiliac Amputation, J Bone & Joint Surg 25 351 1943.
Kirk, N T: Amputations, Dean Lewis Practice of Surgery Hagerstown, Md., W F Prior & Co., 1942.
Langdale-Kelham R. D., and Perkins, G Amputations and Artificial Limbs, London, 1942, Oxford Univ Press.
Le Mesurier A. B. Memorandum on Amputations, Nat. Res. Council of Canada, Bull. War Med. 5 330, 1945 (Abstract)
McCarroll, H. R. Immediate Application of Free Full Thickness Skin Graft for Traumatic Amputation of the Finger J Bone & Joint Surg. 26 489 1944.
McKeever F M.: Upper Extremity Amputations and Protheses, J Bone & Joint Surg 26 660, 1944.
McKittrick, L. S.: Indications for Amputation in Progressive Arterial Obliteration of the Lower Extremities, Ann. Surg 102 312, 1935
Nissen, Rudolph, and Bergmann, Ernst Cineplastic Operations on Stumps of the Upper Extremity New York, 1942 Grune & Stratton.
Orr Thomas G Amputations Christopher Frederick, A Textbook of Surgery Philadelphia, 1936, W B. Saunders Co.
Perkins, G Amputations, Brit. J Surg 31 377 1944.
Rogers, S. P Amputation at the Knee Joint, J Bone & Joint Surg 22 973 1940
Slocum, D. B. Amputations, St. Louis, To be published The C. V Mosby Co.
Slocum, D B., and Pratt, D R. The Principles of Amputations of the Fingers and Hand, J Bone & Joint Surg 26 535 1944
Thomas, A.: Anatomical and Physiological Considerations in the Alignment and Fitting of Amputation Protheses for the Lower Extremity J Bone & Joint Surg 26 645, 1944.
Thompson, T C Amputations: A Comparison of End Bearing and Ordinary Stumps, S. Clin. North America 24 1433, 1944.
Thompson, T C., and Alldredge, R. H Amputations Surgery and Plastic Repair J Bone & Joint Surg 26 639 1944.
Vasconcelos, Edmundo Modern Methods of Amputation, Philosophical Library of New York, 1945.

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